# FORAGE SYSTEMS FOR YEAR-ROUND GRAZING BY LACTATING DAIRY COWS

By

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A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1999

Dedicated with love to

Ângelo, Renata, Ângela, and Magali

# ACKNOWLEDGMENTS

The author expresses his gratitude to Dr. Lynn E. Sollenberger, Professor of Agronomy and chairman of the advisory committee, for his secure guidance, patience, and encouragement throughout the degree program. His high standards and professionalism are important to his students. Special recognition is extended to Dr. Charles R. Staples, Professor of Dairy and Poultry Science, for his support, enthusiasm for the research project, assistance to this beginner, and many suggestions to improving this manuscript. Appreciation is extended to the other Agronomy faculty members of the committee, Dr. Kenneth H. Quesenberry, Dr. Carrol G. Chambliss, Dr. Edwin C. French (in memoriam), and Dr. Ann R.S. Blount, for their good advice, criticism, and guidance, which were most helpful. The author appreciates their willingness to serve on the committee and to review this manuscript. Thanks also are expressed to Dr. Ramon C. Littell for his assistance with the statistical analyses and to Dr. John E. Moore for the many lessons.

Appreciation is also due to several individuals for facilitating the successful completion of the research project. Sid Jones and Dwight Thomas, at the Forage Evaluation Field Laboratory, provided valuable help with field activities. Richard Fethiere and Nancy Carter, at the Forage Evaluation Support Laboratory, and Dr. William F. Brown at the Ona Research and Education Center provided excellent assistance with sample analyses. Jocelyn Jennings, undergraduate students, and the Dairy Research Unit (DRU) staff, provided assistance with milk, blood, and feces samplings, and with general animal management   Fellow students Elide Valencia, Steve Welch, Marjatta Eilitta, John H. Fike, Busoondat Macoon, Yoana Newman, Leonardo Ortega, Liana Jank, Marcos Freire, Loan Ngo, Jean Thomas, Alison Snider, Nadia Douglas, and Elkana Nyambati are recognized for their friendship   Thanks are due to the families of Fabiano Toni and Daniela Lopes, Karina Gramacho and Uilson Lopes, Warley and Cristina Nascimento, and Eveli and Carlos Forcelini for their kindness and hospitality, especially upon our arrival in Gainesville   Thanks are due to Dr Ricardo Reis and family for their friendship and constructive discussions during the writing process   Thanks are extended to members of the Brazilian Student Association (BRASA) for many good times spent together

The author is indebted to Empresa Brasileira de Pesquisa Agropecuária (Embrapa) of the Ministry of Agriculture of Brazil and to Universidade de Passo Fundo for the financial support, which made this graduate training possible, and for many colleagues who continued our work there during these four years. The advice and counsel of former professors were important in guiding the author through the endeavor of this graduate program, including Drs Aino V A. Jacques and Gerzy E. Maraschin at UFRGS, Dr Augusto C. Baier at Embrapa/Trigo, and Dr Erlei M. Reis at UPF

The author is thankful to his wife, Magali, and children, Ângelo, Renata, and Ângela, for their love, understanding, assistance and endurance during the years expended to complete this program. Gratitude and love are extended to his parents, Reginaldo and Olga Fontaneli, parents-in-law, João and Nadir Grando, brothers for their support and encouragement, and most important, to God for consistently guiding me in the right way

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Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

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By

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December 1999

Chairman: Dr. Lynn E. Sollenberger
Major Department: Agronomy

As most research with pasture systems for lactating cows has been short term, prolonged lactation studies are needed to better assess their potential. Three experiments were conducted targeting evaluation of year-round forage systems for grazing by lactating dairy cows. Two of them were designed to refine management recommendations, and the third was developed to test year-round production systems that showed potential in the earlier trials. In the first experiment, forage distribution and forage nutritive value were improved and autumn forage deficit was reduced by planting pearl millet (*Pennisetum glaucum* [L.] R.Br.) and sorghum-sudangrass (*Sorghum bicolor* [L.] Moench) genotypes at multiple planting dates and utilizing frequent harvests. In the second trial a combination of planting dates and choosing appropriate mixtures of small-grains, ryegrass (*Lolium multiflorum* Lam.), and clovers (*Trifolium* spp.) allowed production of forage for grazing from late December to May (4 to 5 mo), a period in which perennial warm-season grasses lack both the production and nutritive value necessary for lactating dairy cows. The third trial had two main objectives to compare milk production and composition from two pasture-based systems for lactating dairy cows with those of a confinement housing system, and to compare feeding costs per unit of milk produced among the three systems. In a 276-d experiment, three multiparous Holstein cows were assigned at calving to each of four replicates of two pasture systems. System 1 winter pastures were a mixture of rye (*Secale cereale* L.), ryegrass, crimson clover (*Trifolium incarnatum* L.) and red clover (*T. pratense* L.), while during summer, cattle grazed pearl millet. System 2 included a rye-ryegrass mixture during winter and bermudagrass (*Cynodon dactylon* [L.] Pers.) during summer. Supplement was fed to cows on both pasture treatments at rates of 1 kg per 2.5 kg of milk produced during winter and 1 kg of supplement per 2 kg of milk in summer. Sixteen cows were assigned to the confinement housing treatment, fed a total mixed ration, and cooled by fans and misters. Cows in confinement produced 20% more milk (29 vs. 24 kg milk cow$^{-1}$ d$^{-1}$) than those on pasture systems, there were no differences between Systems 1 and 2. Grazing cows lost more weight than confined cows. Pregraze herbage mass averaged 2.3 and 3.6 Mg ha$^{-1}$ for winter and summer, respectively, however, during August through September pearl millet pregraze mass was reduced to about 1 Mg ha$^{-1}$. Average total intake of pasture cows was 21.8 kg of dry matter cow$^{-1}$ d$^{-1}$ of which 12.0 was from pasture. Economic analyses suggest that System 2 had the lowest feed cost per unit of milk produced and that pasture systems based on perennial forages may be more likely to succeed than those based on annuals, even annuals of high forage quality

# CHAPTER 1
# INTRODUCTION

The dairy industry is a major generator of revenue for the state's economy, with cash receipts from milk marketing totaling $408 million in 1997 (Florida Department of Agriculture and Consumer Service, 1998). Confinement housing and feeding of byproduct fiber sources and conserved forages as components of total mixed rations characterize the Florida dairy industry. Confinement systems are generally overcapitalized with high overhead costs requiring high milk production per cow, however the critical aspect is net profit (Burns and Bagley, 1996). Despite inherently high feed costs, this system has been profitable due to relatively high and stable milk prices, however, in recent years, dairy producers have been experiencing a severe cost-price squeeze due to widely fluctuating milk prices and increasing input costs (Muller et al., 1995; Bull, 1995). Dairy farmers are seeking for ways to remain viable, and some of the alternative systems being considered put greater emphasis on homegrown forage as a feed source.

Use of pasture can reduce feed costs, which may represent more than 50% of total costs, and consequently, increase returns per cow (Parker et al., 1992). This is a major reason for the movement among dairy producers to increase the utilization of pasture as a forage for dairy cows (Muller et al., 1995). Well managed pastures that maximize pasture production and quality are of comparable or better quality than forage produced using mechanical harvesting systems (Muller et al., 1995). In the UK, the relative economic costs on a metabolizable energy (ME) basis of grazed herbage, conserved forage, and concentrates have been estimated to be a ratio of 1:2:4.5 (Leaver, 1985), however the value of forage is best understood in the context of its contribution to livestock production (Sollenberger and Cherney, 1995), especially in intensive systems such as for lactating dairy cows.

Milk production based on intensively managed pasture is a fast growing production system in all parts of the USA as a means of increasing profits (Bertrand, 1998), and has been important in New Zealand for many years (Hanson et al., 1998b). The key concept is substituting the cow for expensive machinery in the harvest of forages.

Pasture for dairy cows is not new, even in Florida. Reeves (1956) stated that "pastures generally are the cheapest source of feed and dairy cattle can use large proportions of quality forage in supplying their nutritive requirements". As the percentage of feed obtained from pasture increased, production costs decreased for the Florida herds enrolled in the 1953 Dairy Herd Improvement Association program". In the last 5 yr some producers in Florida have adopted pasture-based systems that rely on grazing of perennial warm-season grasses. These forages may not be sufficiently high in quality during summer and do not supply adequate quantity or quality during late fall through spring. Summer-annual grasses, such as pearl millet (*Pennisetum glaucum* [L.] R. Br.) and sorghum (*Sorghum bicolor* [L.] Moench) may be valuable forage sources in development of year-round forage systems where quality is important. Cool-season annual grasses and legumes have potential to fill quantity and quality gaps associated with production of perennial warm-season grasses. These cool-season species are of interest because they produce some of the highest nutritive value forage that can be grown worldwide.

Milk yields are generally superior in confinement systems compared with grazing systems (Blaser et al., 1986). It is assumed that production per cow will fall when shifting from a mixed ration to a grazing system, however, when keeping in mind the goal of net farm income, cost reductions may offset this loss. A return to pasture-based milk production has been an option that many dairy farmers have chosen and more are considering (Moore, 1998), because dairy producers have little, if any, control over the price of milk. In this environment, reducing production costs or expanding into large production units are the two primary choices for those desiring greater income (Moore, 1998).

Supplemental feeding of grain (energy) and additional undegradable protein are needed under most conditions to maximize cow performance, particularly with high producing cows in early lactation (Muller et al., 1995). High producing cows cannot meet energy requirements for maximum milk yield from forage alone (Gulyean and Goetsch, 1993). A correct combination of warm-season and cool-season pastures, properly supplemented with protein and energy, can make the dairy enterprise more profitable.

The development of forage systems for year-round grazing by lactating dairy cows is challenging in subtropical regions such as in Florida, due to varying nutritive value of forage throughout the year, heat stress, and the difficulty of quantifying animal nutrient intake on pasture. Because most of research done with pasture-based systems has been short term in nature, longer, full-lactation comparisons of pasture and confinement systems are needed. Three experiments were conducted targeting evaluation of year-round forage systems for grazing by lactating dairy cows. Two were preliminary to refine agronomic management information for year-round pasture systems. The first was designed to compare seasonal DM distribution of pearl millet and sorghum-sudangrass genotypes planted at different dates, harvested frequently, and fertilized liberally with the intent of addressing the potential of warm-season annual grasses for pasture-based dairies. The objective of the second trial was to determine the effect of planting date on forage yield, forage distribution, and nutritive value of six cool-season forage mixtures. The third and primary experiment was conducted to compare pasture-based and confinement systems for lactating dairy cows over a period from January to October 1998. The two main objectives were 1) to compare milk production and composition from pasture-based systems for lactating dairy cows with those of a conventional confinement housing system, and 2) to compare feed costs per unit of milk produced for the two pasture systems and a conventional confinement housing system.

# CHAPTER 2
# LITERATURE REVIEW

## Summer-Annual Pastures

### General

Sorghums used for forage in USA include grain and forage sorghums and sudangrass (*Sorghum bicolor* [L.] Moench), formerly classified as *S. sudanense* [Piper] Stapf (Fribourg, 1995, Harlan and de Wet, 1972). *S. bicolor* is a very large and complex taxa containing the annual domesticated sorghums, the annual wild sorghums, and hybrid swarms among them (Poehlman and Sleper, 1995). Harlan and de Wet (1972) partitioned sorghum variation into five basic races (bicolor, guinea, caudatum, kafir, and durra) and all combinations of their hybrid derivatives, for a total of 15 races and sub-races that are the commonly used agronomic groups (feterita, kaura, sorgo, sudangrass, etc.) familiar to sorghum workers.

Pearl millet (*Pennisetum glaucum* [L.] R. BR.) and sorghums originated in Africa. They are important grain crops for human nutrition in several countries of Africa, India, and Pakistan, however, the major use in USA, South America, Australia, South Africa, Israel, and Italy is fodder (FAO, 1990, Andrews and Rajewski, 1995). They are widely used for grazing and silage for beef and dairy cows. Pearl millet may be used as a feed grain for beef cattle, but diets should be formulated to efficiently utilize the high quantity of protein (about 14% of the dry matter [DM]) as a substitute for supplemental protein

(Hill and Hanna, 1990). Hill et al. (1996) reported that pearl millet supplied approximately 88% as much net energy for maintenance and 85% as much energy for gain as the corn-soybean meal portion of diets having similar crude protein (CP) concentrations.

Pearl millet and sorghum-sudangrass species are annuals, erect, 0.5- to 5.0 m-tall, leafy, drought tolerant, and responsive to N. Yields are high, but occur over a short season, generally from June to August (Ball et al., 1991, Chambliss et al., 1999). Some sorghums can produce more DM ha$^{-1}$ than corn. The forage nutritive value is high when harvested at an immature growth stage. The species are valuable in the development of year-round forage systems where forage nutritive value is particularly important, such as with lactating dairy or rapidly growing animals. Grazing of pearl millet and sorghum by growing beef cattle is done on an increasing scale in the USA, and feeding of these crops as silage or green chop to lactating cows is a common practice in intensive dairy enterprises (Fribourg, 1995).

Pearl millet grows on a wide range of soils but generally prefers better drained ones and is particularly well suited to sandy soils. For this reason, it is recommended for regions overlapping those of sorghum cultivation, but above 400-mm isohyet (line of equal rainfall). Sorghums occupy the heavier, clay soils, and they are more tolerant of waterlogging and flooding than pearl millet. Although *Pennisetums* often are grown on poor soils, they are responsive to good management and higher fertility levels (Rachie and Majmudar, 1980).

Optimum mean temperatures for growth and development may be somewhat higher for pearl millet, perhaps 2 to 4°C, than for sorghums (Rachie and Majmudar, 1980)

Seeding of millet should not occur before soil temperature at a 10-cm depth reaches 12°C (Fribourg, 1995). Sorghum-sudangrass hybrids should be planted 2 wk after corn planting time when the soil has become warm (USDA, 1969). In the extreme South, the best seeding time for a pasture or hay crop is between 1 April and 1 May. It may be delayed in part of a field intended for pasture or green chop, to allocate production over a longer period. In the case of pasture, the delay fits well in pasture rotation. In the case of green chop, it permits harvesting to occur in stages. Sorghum-sudangrass hybrids can be harvested or grazed three or four times per season (USDA, 1969).

## Yield and Yield Distribution

### Planting date

McCartor and Rouquette (1977) reported that pearl millet was difficult to manage as a grazing crop because of the wide fluctuation in forage production over a relatively short growing season. They indicated that the stocking rate required to maintain a given grazing pressure may vary several fold during a 90-d grazing season, and liveweight gains were difficult to maintain during the grazing season because both quantity and quality of forage were declining.

Better distribution of forage DM can be obtained by soil selection and staggered plantings. Multiple plantings often are made to equalize forage production throughout the season, however they can result in low yields because growth may be hampered by cool fall temperatures, summer droughts, or short days (Fribourg, 1995). In north Florida, Chambliss et al. (1999) recommended that pearl millet and sorghum-sudan hybrids not be planted earlier than 1 April to avoid cool soil conditions. Pearl millet can be planted during mid-summer to obtain a single grazing or harvest in fall (Chambliss et al., 1999) Pearl millet pastures planted following small grain provided grazing for dairy cattle from May to June (depending upon planting date) and usually through the early part of September in Orlando, FL (Marshall et al., 1953)

Causley (1990) in New Zealand studied eight 'Sudax' (*S. bicolor*) planting dates at weekly intervals from 5 November and found that the highest DM yield from February to April was from the first two sowings, although frost damaged the first three plantings The yield decreased from 21,000 to 12,000 kg DM ha$^{-1}$ for the earliest to latest planting dates

Pearl millet, sorghum-sudangrass, and sorghum produced higher forage yield, CP yield, and digestible DM yield with an early, rather than a late planting date, in double cropping with barley for silage and wheat for grain (Moomaw and Mader, 1991) The in vitro dry matter digestibility (IVDMD) and CP concentration of pearl millet were not affected by planting date, but both decreased in sorghum-sudangrass from early to later planting dates (Moomaw and Mader, 1991) In Jordan, Hattab and Harb (1991) and Harb and Hattab (1991) reported a reduction in sorghum-sudangrass forage yield with later planting when forage was harvested at a 75-cm height following planting in May to July, however, there was no effect of planting date on CP, crude fiber (CF), and IVDMD The CP concentration decreased from 124 to 80 g kg$^{-1}$ DM from the first to fifth harvest, the IVDMD dropped from 540 to 443 g kg$^{-1}$ DM, while the CF increased from 328 to 377 g kg$^{-1}$ DM.

Cultivars

Dunavin et al. (1992, 1993, 1994, and 1995) evaluated several sorghum and pearl millet genotypes at Jay, west Florida, planted most years during April and fertilized with a total of 150 to 200 kg N ha$^{-1}$ in three applications. Total yield from four harvests of 'GK 600' (Agratech), 'Tifleaf 2' (Ga. A.E.S.), and 'Millex 24' (Northrup-King) pearl millets ranged from about 8,000 to 11,000 kg DM ha$^{-1}$, and for 'Hygrazer' (Conlee sorghum-sudangrass) and 'SX 15' (Dekalb sorghum-sudangrass) ranged from about 7,000 to 11,000 kg DM ha$^{-1}$.

Tifleaf 2 (Hanna et al., 1988), a dwarf pearl millet cultivar similar to 'Tifleaf 1' (Burton, 1980), is resistant to rust (*Puccinia substriate*) and leaf spot (*Pyricularia grisea*). Tifleaf 2 presented DM yield of 11.4 t DM ha$^{-1}$ in a 3-yr trial, and IVDMD was 660 and 607 g kg$^{-1}$ DM in samples harvested in late July and late September, respectively (Hill et al., 1989 and 1995). Mulcahy and Stuart (1987) tested 13 forage sorghum cultivars in southeast Queensland, Australia with yields ranging from 10,800 to 16,500 kg DM ha$^{-1}$.

Defoliation, Forage Nutritive Value and Quality

To survive repeated partial defoliation, plants develop morphological adaptations to protect meristems, but if the apex is grazed, persistence depends on regrowth of existing tillers, or initiation of new tillers from axillary buds (Chapman and Lemaire, 1993). Removal of the apical meristem may increase tillering and force favorable morphological changes that result in higher nutritive value of grazed pearl millet and sorghum-sudangrass.

Plant regrowth depends not only on the amount and type of tissue removed, but also the stage of plant development and the prevailing plant's abiotic and biotic environment. Light, water, and nutrients are abiotic conditions that may limit growth. The age and type of tissues removed strongly influence how rapidly a plant can recovery. For instance, loss of older leaves affects regrowth less than younger ones. Removal of meristematic tissue has a greater proportional effect on regrowth rate than loss of biomass (Richards, 1993). Recovery of summer-annual grasses depends on amount of photosynthetic tissue left on the stubble, and the presence and regrowth of terminal, axillary, and basal meristems. The DM yield and distribution are affected by frequency (time between cuts) and intensity (amount of biomass removed) of defoliation. Thus, as the defoliation height is raised, regrowth from terminal meristems increases, whereas basal and axillary tillering increases as the point of defoliation is lowered. Pearl millet is more sensitive to lower stubble height than are some sorghum cultivars. Stubble lower than 10 to 15 cm may result in reduced regrowth or even death of the plant. Most uniform grazing and least waste are achieved by initiating grazing when plants are 50- to 70-cm tall, however greatest DM yields are obtained when plants approach maturity or attain heights of 80 to120 cm. Rotational stocking or strip grazing provide optimum management where two or more areas are grazed successively in a controlled manner (Fribourg, 1995). A thin-culmed sorghum or pearl millet regrows more rapidly after cutting than thicker stemmed types, therefore thin-culmed types can tolerate closer grazing or harvest (Fribourg, 1995).

### Leaf percentage and leaf:culm ratio

The simplest way to genetically increase the leaf percentage in grasses is to decrease the amount of culm by incorporating a dwarf gene (Burton et al., 1969). The dwarf $d_2$ gene in inbreds 'Tift 23Db' and 'Tift 23B' increased leaf percentage, IVDMD, and CP of culms (Burton et al., 1969). The dwarf $d_2$ gene in pearl millet, reduces the internode length, plant height, and culm percentage (Burton and Fortson, 1966). Dwarf plants, although lower yielding, have 15% more protein and 17% less lignin than tall plants (Burton et al., 1969). Forage from dwarf pearl millet was higher in IVDMD than forage from tall plants and there were no differences in IVDMD of leaf and culm components. This indicated that the higher IVDMD of dwarf genotypes (Hanna et al., 1979) was due to a higher leaf percentage than for the tall genotypes (Burton et al., 1969). Young leaf blades may approach 750 g kg$^{-1}$ DM of IVDMD, while old leaves may be only 500 to 600 g kg$^{-1}$ DM, and culms may be as low as 300 to 500 g kg$^{-1}$ DM (Fribourg, 1995). Differences in forage nutritive value between genotypes were generally found to be greater at late rather than at early stages of growth. Dwarf or semi-dwarf pearl millets include 'Tifleaf 1', 'Tifleaf 2', and 'Tifleaf 3'. They are more leafy and easier to manage under grazing than tall types (Chambliss et al., 1999).

### Forage nutritive value

Chemical composition of forages is influenced by growth stage, season of year, plant part sampled, soil nutrient status, and soil pH (Nelson and Moser, 1994; Frame et al., 1997). Although age and maturity have a larger influence on forage quality than environmental factors, such as temperature, water deficit, radiation, soil nutrients, and insects and diseases, these factors cause deviations in forage nutritive value (Buxton and

Fales, 1994). Nelson and Moser (1994) stressed the importance of a good characterization of forage species, cultivars, stage of maturity, and environmental conditions during growth when animal performance is reported.

Hanna et al. (1979) reported IVDMD of 660 g kg$^{-1}$ DM at anthesis of pearl millet inbred 23DA, dropping to 594 to 605 g kg$^{-1}$ DM 2 wk later. Monson et al. (1969) using a nylon bag method, reported DMD for dwarf pearl millet leaf and stem fractions at five dates of sampling separated by 2-wk intervals. Leaf DMD decreased from 768 to 657 g kg$^{-1}$ DM and culm DMD from 688 to 548 g kg$^{-1}$ DM in samples collected at a progressive stages of maturity from 21 August.

Pearl millet digestible DM concentration decreased from 786 to 559 g kg$^{-1}$ DM and net energy for lactation (NEL) decreased from 6.08 to 5.18 MJ kg$^{-1}$ for plants at three-leaf stage and heading stages, respectively (Kim and Han, 1990). The best time for harvesting to optimize DM production and quality would appear to be between the bloom and dough stages. When the green chop is harvested after 2 and 3 mo of growth the CP concentration of pearl millet decreased from 10.9 to 5.3% (by 50%), but sorghum CP declined about a third with a similar advance in maturity (Rachie and Majmudar, 1980). Messman et al. (1992) reported that pearl millet silage with 23.4% DM had 12% CP, 66.6% NDF, and 42.5% ADF. They did not find differences in milk production comparing pearl millet silage, pea-triticale silage, and a control (alfalfa and corn silage). Pearl millet cv. 'Comum' in south Brazil, yielded 10,700 kg DM ha$^{-1}$ in four harvests with average CP concentration of 196 g kg$^{-1}$ DM (Freitas, 1988).

Forage quality

Differences in forage quality should be expressed through differences in animal performance (e.g., daily gain, milk production, etc.) when animal potential and forage quantity are not limiting, and no supplemental energy and protein are provided (Moore, 1994). Animal gain is influenced by many animal and plant factors, most notably dry matter intake and digestibility (Coleman et al., 1989). For instance, intake of a dairy cow depends upon many variables including liveweight, level of milk production, stage of lactation, environmental conditions, management and social factors, previous feeding history, body condition, and type and quality of feed ingredients, particularly forages (NRC, 1989).

Well managed summer-annual grass pastures can result in animal performance similar to that from alfalfa (Fribourg, 1995). Marshall et al. (1953) studied pearl millet in Florida that was kept in a vegetative and palatable condition by rotational stocking and mowing stubble following each grazing to stimulate production of new shoots. The 3-yr average carrying capacity was 5 cows $\text{ha}^{-1}$ with 13.8 kg milk (fat corrected to 4%), and 4 kg daily concentrate consumption. The CP concentration during the first, third, and fourth rotations of 1952 were 234, 240, and 215 g $\text{kg}^{-1}$ DM, indicating high nutritive value was maintained throughout the grazing season. Alba and Siller (1979), during 12 periods of 5 to 27 d, reported average daily milk production of 13 kg for stargrass (*Cynodon nlemfuensis* Vanderyst) and 17.8 kg for pearl millet cv. 'Apodaca 22'.

Pearl millet was superior to 'Tift' sudangrass or grain sorghum as a summer grazing pasture for lactating dairy cows in Mississippi (Marshall et al., 1953). In a 3-yr experiment, Clark et al. (1965) noted a milk fat depression, averaging 0.13 percentage units, for cows grazing pearl millet relative to those on sudangrass and sorghum-sudangrass hybrid pastures. The difference was accentuated by high grain supplement levels. Rachie and Majmudar (1980) reported a milk fat depression in dairy cows for millet (2.85%) compared with sudangrass (3.64%). Decreased fat concentration of milk was accompanied by a reduction in the saturated fatty acid concentration, but this decline was corrected by supplementing with sodium acetate. Cows grazing pearl millet supplemented with 8 kg $d^{-1}$ of concentrate produced 20 kg $d^{-1}$ of milk, but fat decreased 21% from that of cows grazing sudangrass (Miller et al., 1965). Messman et al. (1992) did not find differences in milk fat concentration comparing pearl millet silage, pea-triticale silage, and a control (alfalfa and corn silage), but reported lower milk protein for cows fed pearl millet than for the controls. The authors suggested that a depression in protein concentration could been caused by reduced energy intake.

Beef cattle gain of 1 kg per animal per day on sudangrass pastures are common (USDA, 1969). Pearl millet is capable of producing daily liveweight gain of about 1 kg $animal^{-1}$ and up to 400 kg $ha^{-1}$ during a 90-d grazing period (McCartor and Rouquette, 1977). During 2 yr, Johnson et al. (1978) evaluated the performance of dairy heifers grazing 'Gahi 3' and Tifleaf 1 millets relative to that of heifers grazing Gahi 1, a widely grown hybrid millet. After plant height reached 45 to 50 cm, the millets were grazed for 56 d. Heifer initial liveweight was 315 and 268 kg in the first and second years, respectively. The stocking rate was 7.2 and 8.8 animals $ha^{-1}$ in the 2 yr. Daily gain per animal over both years averaged 0.63, 0.76, and 0.84 kg from Gahi 1, Gahi 3, and Tifleaf 1, respectively.

Dwarf pearl millet supported fewer steer days than tall millet, but the steer gain per hectare was the same due to a 20% better daily gain (Burton et al., 1969). Yearling heifers grazing Tifleaf 2 gained 0.64 kg $d^{-1}$ and yielded 411 kg $ha^{-1}$ (Hill et al., 1989 and 1995).

Josifovich and Ceressetto (1989), in a trial at Pergamino, Argentina, stocked steers weighing 334 kg for 81 d on sorghum-sudangrass cv. 'Sudancross 2' and for 73 d on pearl millet cv. 'Selection Pergamino', a new dwarf cultivar. Initial DM availability was lower in pearl millet than sorghum but regrowth was greater in pearl millet. Daily weight gains per animal were 0.67 kg with a stocking rate of 5.7 animals $ha^{-1}$ on sorghum and 0.58 kg with 5.8 animals $ha^{-1}$ on pearl millet. Total beef production was 325 kg $ha^{-1}$ for sorghum and 261 kg $ha^{-1}$ for pearl millet.

In Brazil, Coser and Maraschin (1983) reported no differences in animal gain between pearl millet cv. Comum and sorghum cv. 'Sordan NK'. Heifer average daily gain was 0.78 and 0.71 kg, whereas the liveweight gains were 479 and 401 kg $ha^{-1}$ on pearl millet and sorghum pastures, respectively. Moraes and Maraschin (1988) reported a positive linear relationship between animal gain and forage allowance for steers grazing pearl millet cv. Comum. As grazing pressure decreased, the daily liveweight gain increased from 0.50 to 1.24 kg, the animal days $ha^{-1}$ increased from 334 to 604, while gain per area increased from 259 to 572 kg.

Pearl millet was evaluated during 3 yr from July to September in North Carolina as creep grazing pasture and compared with a red clover-Kentucky bluegrass (*Poa pratensis* L.) control. Calf average daily gains on Tifleaf pearl millet ranged from 1.05 to 1.09 kg, but were similar to the control (Harvey and Burns, 1988). In that environment, both pearl millet and red clover can provide high quality forage during the summer stress period.

## Forage-Livestock Systems Using Annual Warm-Season Grasses

Summer-annual grasses are used worldwide as a component of production systems to improve forage yield, forage distribution, and nutritive value in intensive year-round forage systems such as for lactating dairy cows. Belesky et al. (1981) in Georgia increased and improved forage distribution for year-round grazing by seeding sorghum-sudangrass hybrids into a tall fescue (*Festuca arundinacea* Schreb.) sod after the flush of spring growth by fescue, and by seeding rye (*Secale cereale* L.) in early October. A tall fescue monoculture yielded 7,400 kg DM ha$^{-1}$ yr$^{-1}$, while the fescue-sorghum-rye system yielded 11,100 kg DM ha$^{-1}$ yr$^{-1}$. Sorghum accounted for 48% of the total DM yield.

In the New Zealand dairy forage system, ryegrass-white clover is insufficient for optimal animal grazing during the summer. 'Sudax' sorghum-sudangrass hybrid produced 6,000 kg DM ha$^{-1}$ vs. 2,800 kg DM ha$^{-1}$ for ryegrass-white clover pasture during summer-early fall. In a system consisting of 25% Sudax and 75% pasture, Sudax contributed 55 to 59% of the summer diet. The composition of the Sudax consumed was 40% leaf blade, 18% sheath, 38% stem, and 4% inflorescence. The IVDMD was similar to that of pasture (669 vs. 660 g kg$^{-1}$ DM), and over an 82-d experiment daily liveweight gains were 0.89 and 0.85 kg for pasture plus Sudax vs. pasture alone (Causley, 1989).

Muehlmann et al. (1997) in Brazil compared summer pastures for early weaned (94 d) bovines weighing 84 kg. In a 83-d experiment (7 Feb. to 1 May 1991) during which native grassland, elephantgrass (*Pennisetum purpureum* Schumach.), bermudagrass, and pearl millet were grazed, average daily gain was 0.012, 0.175, 0.314, and 0.257 kg, gain ha$^{-1}$ was 16, 197, 335, and 310 kg, and TDN ha$^{-1}$ was 617, 1861, 1625, and 1854 kg, respectively. Heifers on native grassland had inferior performance compared to that on bermudagrass and pearl millet pastures.

## Bermudagrass

Common bermudagrass (*Cynodon dactylon* [L.] Pers.) is a cosmopolitan weed (Harlan and de Wet, 1969), forage, and turfgrass. According to Harlan (1970) there is no record of the first USA introduction of bermudagrass. Because it can be propagated by seed yet has stolons and rhizomes it is easily spread, and it was a difficult weed problem for most southern farmers interested in growing cotton (*Gossypium spp.*) and corn (*Zea mays* L.). Coastal bermudagrass released in 1943 can be considered a landmark for livestock development in the southeastern USA (Harlan, 1970). Due to better forage yield, and lack of seed production, and fewer rhizomes than common bermudagrass it is less aggressive. According to Burton and Hanna (1995), although bermudagrass cultivars need to be planted vegetatively they occupy about 10 million ha worldwide.

Bermudagrass and tall fescue have been termed unsuitable forage resources for high-producing dairy cows (Wangsness and Muller, 1981) because they require considerable supplemental concentrate to sustain high production (Burns and Bagley, 1996). Burton and Hanna (1995), however, reported that cows on a four-pasture rotation in which lactating dairy cows grazed new growth of 'Coast-cross 1' bermudagrass in a leader-follower system, produced 4550 kg of milk per lactation without any concentrate.

'Tifton 85' is a hybrid between a South African bermudagrass introduction and Tifton 68 (*C. nlemfuensis*) developed at Tifton, GA. Burton et al. (1993) described it as taller, with larger culms, broader leaves, and darker green color than other bermudagrass hybrids. Tifton 85 yielded 26% more DM, was 11% more digestible, and more succulent at harvest than Coastal (Burton et al., 1993). Hill et al. (1993) reported greater yield of Tifton 85 relative to Tifton 68 (18,600 vs. 15,200 kg DM ha$^{-1}$) in 3-yr clipping trial, however, IVDMD was higher in Tifton 68 (636 vs. 603 g kg$^{-1}$ DM), while Coastal yielded 15,500 kg DM ha$^{-1}$ with mean IVDMD of 543 g kg$^{-1}$ DM.

Fike et al. (1997a,b) evaluated Tifton 85 bermudagrass and Florigraze rhizoma peanut (*Arachis glabrata* Benth.) pastures that were intensively managed for grazing by lactating cows in Florida. Cows were fed concentrate at a rate of 1 kg for either 2 or 3 kg of milk of daily milk production. Rhizoma peanut had higher CP (191 vs. 135 g kg$^{-1}$ DM) and IVOMD (713 vs. 628 g kg$^{-1}$ OM) and lower NDF (455 vs. 804 g kg$^{-1}$ DM) than bermudagrass, resulting in an additional 1.1 kg milk cow$^{-1}$ d$^{-1}$. Average milk yield per hectare of two stocking rates was lower on rhizoma peanut than bermudagrass pastures (42.2 vs. 54.6 kg ha$^{-1}$ d$^{-1}$). Rhizoma peanut had higher daily milk production per cow at 5 cows ha$^{-1}$ (17.3 kg) than at 7.5 cows ha$^{-1}$ (16.6 kg), but milk yield per hectare increased from 34.5 (5 cows ha$^{-1}$) to 50 kg ha$^{-1}$ d$^{-1}$ (7.5 cow ha$^{-1}$), while bermudagrass pastures had the highest daily yield per cow (15.9 kg) and per hectare (63.5 kg) with 10 vs. 7.5 cows ha$^{-1}$. The greater stocking rate increased milk production of cows grazing bermudagrass but lowered milk production of cows grazing rhizoma peanut suggesting that nutritive value may have declined due to underutilization of bermudagrass while utilization may have peaked in the rhizoma peanut pastures.

In north central Florida (Pedreira et al., 1998) compared Florakirk and Tifton 85 bermudagrass pastures continuously stocked with yearling beef heifers during a 3-yr trial (160 d yr$^{-1}$) using a variable stocking rate and receiving 210 kg ha$^{-1}$ N in four applications yr$^{-1}$. Average daily gains were the same for the two cultivars (0.6 kg). Tifton 85 herbage was 30 g kg$^{-1}$ OM more digestible than Florakirk (562 vs. 531 g kg$^{-1}$), but CP concentration was similar and annual means ranged from 105 to 132 g kg$^{-1}$. Because of higher herbage yield, Tifton 85 pastures supported higher stocking rates than Florakirk (6.0 vs. 4.0 heifers ha$^{-1}$), resulting in higher gain per hectare for Tifton 85 (648 kg) than Florakirk (371 kg). The authors reported stand loss for Florakirk, and suggested that it be used only under rotational stocking or for hay.

## Winter-Annual Pastures

### General

Most of the widely adapted and productive cultivated cool-season grasses have their origin in Eurasia and Mediterranean regions (Moser and Hoveland, 1996). Small-grain species, such as wheat (*Triticum aestivum* L. emend. Thell.), oat (*Avena sativa* L.), and rye (*Secale cerale* L.) have been developed from wild ancestors and now are used as grain crops, pasture, silage, and hay (Phillips et al., 1996). Approximately 35% of the cultivated land in the world is used to grow annual cool-season grasses (Phillips et al., 1996). Small grains can be grazed during vegetative stages and subsequently still produce grain. They produce high quality forage when warm-season species are not available or have low nutritive value. Another cool-season grass, Italian ryegrass, is one of the most important pasture species in mild climate areas (Jung et al., 1996) because it extends the grazing period, has high nutritive value, is compatible with and easy to establish in warm-season perennial grass pastures, and is tolerant of different defoliation regimens and stocking rates. The importance of the small-grains and ryegrass in the southern USA can be assessed by considering the seed market, the annual sale of seeds is enough to plant 6 million ha of winter pastures (Moser and Hoveland, 1996).

Cool-season legumes are high in quality and result in improved animal performance. Red clover (*Trifolium pratense* L.) is a short-lived perennial that persists for 1 to 3 yr, but usually under Florida conditions behaves as a winter annual. 'Cherokee', developed in Florida, is the highest yielding cultivar, it produced about 8,000 kg DM $ha^{-1}$ at Gainesville in four harvests from late January to June (Chambliss and Quesenberry, 1996). It is the only variety currently recommended for Florida forage producers (Stanley, 1999a). Crimson clover (*Trifolium incarnatum* L.) is a winter annual often seeded in mixture with small grains and ryegrass. It flowers and stops growing about mid-April (Stanley, 1999b).

## Yield and Yield Distribution

### Planting date

Cool-season grasses require temperatures between 20 and 25°C for optimum growth. When temperatures are below 10°C or above 25°C growth drops rapidly. Slow growth occurs at 5°C and may cease above 30 to 35°C even if soil moisture is adequate (Moser and Hoveland, 1996). Cool-season forages are planted at the beginning of the fall, but soil moisture is the most critical factor in determining when to start planting. In north central Florida annual cool-season grasses generally should be planted from 15 October to

15 November and ryegrass from 1 October to 15 November. Earlier planting increases risks of high temperature and inadequate moisture, as well as competition from warm-season species and greater susceptibility to insects and fall leaf diseases (Chambliss, 1999). Small grains sown for forage should be seeded 3 to 4 wk earlier than for grain production alone. Frame et al. (1997) recommended sowing red clover-grass mixtures early in the season to ensure satisfactory establishment of red clover relative to that of the grass, however forage legumes are more sensitive to low temperatures than cool-season grasses (Fales et al., 1996). Crimson and red clover are recommended to be seeded in Florida from 1 October to 15 November (Chambliss, 1999). Evers et al. (1997) suggested that in Texas optimum planting time for annual ryegrass is September on prepared seedbeds or October if over-seeded on a warm-season perennial grass. Planting in September carries with it the risk of seed germination from existing moisture or light rain followed by subsequent seedling death from drought. On the other hand, Ball et al. (1991) indicated that October rainfall is normally low and undependable in the eastern part of the South, often delaying establishment. Alison and Ashley (1993) recommended mid-October as the optimum time for overseeding annual ryegrass on warm-season perennial grass in the lower South. Thus, over-seeding cool-season species should occur when temperatures are cool enough to limit growth and competition from the warm-season grass and when moisture is sufficient to allow seedling emergence and survival from seed planted at or near the soil surface.

Elder (1960) reported the effect of planting dates at 2-wk intervals from 10 September to 25 November on forage distribution and concluded that although the 10 October planting made more growth after early November than did the 10 September planting, the first planting date had produced more than twice as much total forage by January. The same author evaluated the mixture of rye-oat-vetch (*Vicia* spp.) during a 6-yr trial. He reported ADG of 0.7 kg, a stocking rate of 2.7 animals ha$^{-1}$, and gain ha$^{-1}$ of 260 kg during 140 d on pasture, 100 d of which were grazing during winter.

In the Tennessee Valley, Hoveland and Alison (1982) reported that red clover (*T. pratense* L.) and ladino clover (*T. repens* L.) with rye-ryegrass furnished higher total yield than other winter-annual legumes or rye-ryegrass plus 227 kg N ha$^{-1}$. Further south, in Alabama, winter annual legumes such as arrowleaf (*T. vesiculosum* Savi) and crimson clover (*T. incarnatum* L.) were equally productive.

Forage yield and yield distribution

Forage production of annual cool-season grasses may be separated in two phases (fall and spring) and two types of growth (vegetative and reproductive). The vegetative phase, usually in the fall, represents one-third to one-half of total DM production and is composed almost exclusively of leaf, while the reproductive phase in the spring, characterized by rapidly growing plants with more culm, represents one-half to two-thirds of the total (Phillips et al., 1996).

Annual cool-season grasses may be available for grazing in the South from November to May (Phillips et al., 1996) and are used to fill the fall and winter void of system based on warm-season perennials. Rouquette et al. (1997) agreed that these species can provide fall grazing when planted on prepared seedbeds, however, most areas are sod-seeded, which may not provide continuous forage production in the southeastern USA until late December to mid-February.

Rye is more productive than other annual cool-season grasses on sandy, well-drained soils of low fertility, while oat, wheat, and barley do not grow as well on very sandy soils (Phillips et al., 1996). Oat grazed by lactating dairy cows had an average carrying capacity of 2.7 cows ha$^{-1}$, however, because it furnished less forage during early January to mid-February than during fall and early spring, forage should be allowed to accumulate in fall for use during the colder period (Marshall, 1957).

Rye produces more fall forage than spring forage, while oat production is variable and usually the lowest of the annual cool-season grasses (Phillips et al., 1996). Mixtures of species are used to increase forage production, to lengthen the forage production season, to improve forage nutritive value late in the season, and to reduce the risk due to weather conditions. In practice, mixtures of small-grains and annual ryegrass are often used in grazed forage systems (Bagley et al., 1988). Bransby and Gamble (1993) compared animal performance of 'Bonel' rye alone or rye plus 'Marshall' ryegrass. The mixtures resulted in higher stocking rate (3.7 vs. 5 animals ha$^{-1}$) and higher ADG (1 vs. 1.1 kg), which led to higher gain per hectare (380 vs. 520 kg).

Annual ryegrass is very tolerant of frequent and severe defoliation and often supports 2000 kg ha$^{-1}$ body weight for a 75- to 100-d period in the spring (Rouquette et al., 1997). Combining clovers with ryegrass provides animals with a potentially higher nutritive value diet, however, in Texas most of the DM production from legumes overlaps with that of ryegrass during late winter to late spring. When ryegrass is used with small grains it generally provides forage for grazing during fall as well as during winter months (Rouquette et al., 1997).

Limitations of autumn forage production were illustrated by Hoveland et al. (1991) in a 3-yr trial. Daily gains of crossbred steers grazing tall fescue fertilized with 136 kg N ha$^{-1}$, tall fescue-birdsfoot trefoil (*Lotus corniculatus* L.), tall fescue-clover, and rye-ryegrass-crimson-136 kg N ha$^{-1}$ averaged 0.88, 1.02, 1.05, and 1.08 kg, respectively. Autumn grazing was obtained only from 3 Oct. to 16 Dec. 1985 on tall fescue treatments, and from 5 November to 16 December on winter annuals. Nitrogen fertilizer was applied at 68 kg ha$^{-1}$ in September and again in February each year to the tall fescue-N and the winter annuals-N. Except for 34 kg N ha$^{-1}$ at planting no N was applied to the tall fescue-clover or tall fescue-birdsfoot trefoil pastures.

## Forage Nutritive Value and Quality

### Forage nutritive value

Cool-season grasses, when utilized in the vegetative stage, are high in digestible energy and protein (Moser and Hoveland, 1996). The differences in chemical composition between cultivars were probably due to differences in the stage of maturity and the time of harvest (Barnett and Stanley, 1976). Minson and McLeod (1970) summarized in vivo digestibility data from various studies that included over 500 cool- and warm-season grasses. They reported that cool-season grasses averaged 128 g kg$^{-1}$ higher in digestibility than warm-season grasses. Ulyatt (1981) reported average digestibility over the season of about 700 g kg$^{-1}$ for cool-season grasses. Cool-season forages in vegetative stages of growth usually have digestibility higher than 700 g kg$^{-1}$ DM, and sometimes exceed 800 g kg$^{-1}$ DM in the first weeks of the grazing season. The CP concentration of cool-season species ranges from 200 to 300 g kg$^{-1}$ DM, and the leaf tips that are grazed are sometimes greater than 300 g kg$^{-1}$ DM (Lippke and Ellis, 1997, Frame et al., 1997).

Forage quality

Animal performance on cool-season grass pastures is generally very good due to high nutritive value and compensatory gain if animals had been on a relatively low plane of nutrition (Moser and Hoveland, 1996). For animals on a high level of nutrition, such as dairy cows fed corn silage, performance may drop when grazing cool-season grasses. This occurs because the energy level may not be adequate, thus supplementation of energy and rumen bypass protein may enhance animal performance with lush cool-season grass pastures, such as wheat and ryegrass, even though they are high in digestibility and degradable protein (Moser and Hoveland, 1996).

Milk production per hectare from cool-season grasses in Europe ranged from 5500 to 29000 kg ha$^{-1}$ and about 6000 kg cow$^{-1}$, while in New Zealand it was 10,400 kg milk ha$^{-1}$ and 540 kg fat ha$^{-1}$ when no concentrate was fed (Burns and Bagley, 1996). The greatest production per area, in the Netherlands, was due to high N fertilizer inputs and very high stocking rate (4.8 cows ha$^{-1}$) because the milk production per cow 5980 kg was similar to that obtained in several European countries (Burns and Bagley, 1996). These authors cited several references in which milk production per cow ranged from 6 to 11 kg d$^{-1}$, however, with stocking rates used in these situations, milk production on a per-unit land basis ranged from 4000 to 18,000 kg ha$^{-1}$. Clark et al. (1966) reported fat corrected milk (FCM) yields of 8900 kg ha$^{-1}$ from a ryegrass-'Midland' bermudagrass grazing system on which lactating cows produced an average of 16.7 FCM d$^{-1}$. This amount exceeded that from orchardgrass alone by over 2900 kg ha$^{-1}$ and an orchardgrass-ladino clover mixture by 3500 kg ha$^{-1}$.

Rouquette et al. (1997) described an east Texas system in which grazing cows have access to hay ad libitum, are rotationally stocked on ryegrass-rye pastures at stocking densities of about 50 cows ha$^{-1}$ and are moved to new paddocks a twice-a-day. In this system, milk production has been limited to about 6350 to 6810 kg cow$^{-1}$ yr$^{-1}$, with net returns to management exceeding expectations.

Long-term (over 100 d) average daily gains (ADG) of beef cattle grazing annual cool-season grasses vary from 0.6 kg to 1.6 kg, while short-term (less than 45 d) ADG may exceed 1.3 kg (Bagley et al., 1988, Dalrymple, 1984). Usual daily gains of calves on ryegrass pastures may be greater than 1 kg and from 450 to 900 kg ha$^{-1}$ (Rouquette et al., 1997).

## Grazing by Lactating Dairy Cows

This section will cover aspects related to intake of herbage, problems related to formulation of adequate diets for high producing lactating dairy cows, and heat stress limitations in Florida grazing systems.

Intake and digestibility of forage are key factors that determine animal performance of grazing animals (Minson, 1990). There is usually a positive relationship between digestibility and daily intake within forage species, however deviations occur among plant species, varieties and plant parts, consequently correlation between digestibility and intake may be low (Buxton and Mertens, 1995). Intake is generally more important than digestibility in causing differences in digestible DM intake (Waldo, 1986).

(Minson, 1990) indicated that intake accounts for approximately 75% of the variation among forages in terms of animal performance, while Mertens (1994) suggested that it accounts for about 60 to 90% and digestibility 10 to 40%  Both intake and digestibility are influenced by proportion of cell wall material and the resistance of fiber structures to breakdown during mastication and digestion (Wilson and Mertens, 1995)  The intake of herbage by lactating dairy cows is the major factor limiting milk production from pasture (Leaver, 1985, Reis, 1998)

There are differences in intake between grasses and legumes, leaf and stem, tropical and temperate species, and even cultivars with the same level of digestibility (Minson, 1990)  Cosgrove (1997) relates that differences in intake are mainly due to forage composition, basically fiber concentration, its retention time and ease of particle breakdown in the rumen. The actual prehension of material by grazing animals is probably influenced by anatomical characteristics that impart structural strength (Wilson, 1997) The well-known selection of leaf by grazing animals is due in part to greater expenditure of energy and time spent chewing during eating of stems compared to leaf (Wilson, 1997) It has been suggested that C4 tropical grass leaves may be tougher and require more chewing during eating than C3 temperate grasses. Wilson et al. (1989) demonstrated this by determining thet the chewed and swallowed leaf particles of green panic were smaller than those of ryegrass

The potential intake of forage varies with physiological status of the animal, for instance, lactating females need more than young growing animals, which need more than mature animals, because the mature animals are only maintaining their body condition (Buxton and Mertens, 1995)  In addition to the animal nutrient requirements, canopy structure and amount of forage and herbage composition are important factors related with the quantity of herbage eaten by grazing animals (Waldo, 1986, Minson, 1990, Cosgrove, 1997). The amount of DM consumed by a milking dairy cow depends on many variables including liveweight, level of milk production, stage of lactation, environmental conditions, management and social factors, previous feeding history, body condition, and type and quality of feed ingredients, particularly forages (NRC, 1989). The ARC (1980) has assumed in the absence of precise evidence of the contrary that intake in dairy cows varies according to $LW^{0.75}$. The intake of herbage by lactating cows is 25-50% greater than by non-lactating cows (Leaver, 1985). NRC (1989) emphasized that the limited DMI data from high-yielding cows and the many variables that affect intake make it difficult to predict maximum DMI with accuracy.

## Theories of Intake Regulation

Management to increase cow's DM intake requires a better understanding of the interactions between sward characteristics, grazing behavior, and forage intake (Reis, 1998). Consequently, intake potential of a forage can be better understood when the relative importance of animal and plant factors is known. The three major regulators of intake by ruminants are physical limitations, physiological control, and psychogenic factors.

### Physical

Physical limitations to intake or gut fill, occur when animals eat until rumen and/or lower intestines reach constant fill, for example when forages with high NDF concentration and low available energy are fed to animals with high energy demands, the intake will be limited by physical fill. Within limits, DM intake increases as the digestibility increases (NRC, 1989), however the relationship between intake and digestibility is not consistent across species or for different components of pastures.

Physiological

Physiological control occurs when animal potential and not forage characteristics is determining intake, for example when high quality forages are fed to animals having only maintenance requirements. When highly digestible diets are fed, energy intake plateaus and DMI actually decreases (Conrad, 1966). Both mechanisms provide a logical basis for understanding intake regulation and estimating intake at the extremes of forage quality, however there may be interactions among the two mechanisms (Buxton and Mertens, 1995), thus making predictions of intake more difficult.

Conrad et al. (1964) concluded that DMI was governed by both the capacity of the digestive tract and by the cow's energy requirement. When diets present low digestibility, intake is regulated physically (fill), whereas when diets present high digestibility, control of intake is physiological. The transition point between both mechanisms of intake control was suggested to be 66.7% digestible DM for a 450-kg cow producing 16.8 kg of milk $d^{-1}$, however Waldo (1986) suggested that this transition point is not fixed and could occur at higher levels of digestibility for higher producing cows.

Forbes (1977) described the relationship between available nutrients and voluntary feed intake in ruminant. There is a positive correlation between the concentration of available energy and the amount of feed eaten for poor- and medium-quality forage. On the other hand, this correlation is negative with high-quality forage and diets with a high proportion of grain concentrates (NRC, 1989).

Cows do not consume as much feed during early lactation as they do during later lactation, even though the milk production level may be the same (NRC, 1989). Journet and Remond (1976) estimate that DM intake is depressed 15% on average during the first 3 wk of lactation relative to later lactation, with the greatest depression occurring during the first days of lactation. Milk production usually peaks between 4 and 8 wk postpartum, while the maximum DM intake usually occurs between 10 and 14 wk postpartum, resulting in a negative energy balance in early lactation (NRC, 1989). The cow consequently mobilizes body tissues, which results in weight loss. As DMI increases and milk production plateaus or begins to decline, weight change stabilizes and little by little increases in mid- and late-lactation, and also during the dry period. Increase in weight during the dry period may also be attributed to the development of the fetus and fetal membranes during the last trimester of gestation (NRC, 1989).

### Psychogenic

Psychogenic factors that influence intake in response to external stimuli include palatability, feed flavors, feed pH, social interactions, stress, diseases, and management.

### Factors Influencing Intake Under Grazing

Intake under grazing conditions can be limited by nutritional factors (digestibility, rumen fill, metabolic factors) and non-nutritional factors including ingestive behavior (i.e., bite weight, bite rate, and grazing time; Moore, 1994). The importance of these factors vary according to plant components of pasture, pasture structure, and the animal.

Appreciation of ingestive behavior effects on intake arose from the observation, first suggested by Stobbs (1973), that certain swards limit the ability of the animal to consume adequate amounts of the animal to consume adequate amounts of herbage. Stobbs (1973) observed that under some conditions pasture leaf density was so limited and bite weight so low that animals could not sufficiently compensate and achieve desired levels of intake by increasing grazing time and number of bites per day. This situation can occur with very low herbage mass or with very high herbage mass of low leaf/stem ratio (Coleman, 1992).

## Measurements of Dry Matter Intake (DMI)

Measurement of intake is one of the most difficult aspects in measuring or predicting forage quality (Buxton and Mertens, 1995). Moore and Sollenberger (1997) cited two general approaches to the indirect estimation of pasture intake: 1) estimates for individual animals, and 2) estimates for groups of animals, or a pasture. Several techniques were developed for each approach with assumptions that must be met in order for estimates to be valid. The techniques applicable to individual animals include fecal output and forage digestibility, and ingestive behavior. Those for groups of animals on a pasture include disappearance of herbage mass, prediction from forage characteristics, or calculation from animal performance.

There are generally a lack of controlled research studies on intake of high producing dairy cows on pasture due to difficulty of estimation. Muller et al. (1995) suggested that pasture DMI could be estimated by subtracting grain and supplemental forage DMI from NRC (NRC, 1989) estimates of total DMI required for a particular level of production. Pasture intake can be estimated through disappearance of herbage mass by measuring differences between herbage mass pre-grazing and post-grazing using a rising plate meter, probe, or visual assessment. The difference between pre- and post-grazing represents total herbage DM consumed for a group of animals and can then be calculated on a per cow basis. Sampling errors are cumulative of pre- and post-grazing sampling, and the CV's are normally larger than animal methods, ranging between 7 and 52% (Walters and Evans, 1979).

In recent years a common technique for estimating intake involves in vitro determination of pasture digestibility (D) and fecal output (FO, kg DM $d^{-1}$) estimated by external markers. Intake (I, kg DM $d^{-1}$) is estimated from: $I = FO / (1 - D)$. The common marker used has been chromium sesquioxide ($Cr_2O_3$) and the pulse dose technique (Pond et al., 1989a,b). Markers are used routinely to calculate daily fecal DM output, as well as several parameters to estimate kinetics within the digestive tract (Moore and Sollenberger, 1997). A non-linear equation is used to describe the relationship between marker concentration and time after dosing (Moore et al., 1992). Moore and Kunkle (personal communication) developed a model to adjust for forage-concentrate interaction effects on intake for lactating dairy cows supplemented on pastures.

### Daily Intake of Cows on Pasture

When high quality pasture is available and when grain is fed at amounts "typical" for these production levels, pasture DMI and total DMI are comparable to the DMI expected with non-grazing cows (Muller et al., 1995). These authors reported results of Rippel (1995) where cattle grazing ryegrass had greater forage and total DMI than those grazing orchardgrass. Addition of 'Alfagraze' alfalfa to ryegrass or orchardgrass resulted in greater forage and total DMI (4% BW) than pure ryegrass or orchardgrass pastures

(3.5% BW). The cows on grass-alfalfa produced 31 kg milk $d^{-1}$, and consumed 22.2 kg total DMI, of which 14.5 kg DM came from pasture.

Herbage intake from well-managed pastures should provide sufficient energy to support daily milk production of 18 to 23 kg with little or no supplemented energy and protein (Muller et al., 1995). Noller (1997) agreed and stated that this production level, although lower than modern standards, may be the most economical level of production. Cows may peak at 27 kg or more of milk per day, but may be expected to lose body condition rapidly and be less persistent in milk production. Since most cows have the genetic potential to produce above 18 to 23 kg per day, supplemental feed and energy are needed to achieve maximum milk production. Thus, because of the availability and relatively low prices of many grains and by-products in relation to milk prices, dairy producers can justify feeding supplements in an attempt to obtain the genetic potential for production and maximum profit from their dairy cows (Muller et al., 1995).

Holden et al. (1994b) estimated total and forage intake of Holstein cows in the northeastern USA on a mixture of orchardgrass (38%), Kentucky bluegrass (*Poa pratensis* L., 34%), and smooth bromegrass (*Bromus inermis* Leyss., 18%) with a stocking rate of 2.5 or 3.9 cows $ha^{-1}$. The daily forage intake ranged from 11.6 to 15.6 kg DM and was lowest in the summer, while the total daily intake increased from 21.3 kg in early spring to 22.4 kg in late spring, and after that it decreased as lactation progressed. In northern Victoria, Australia, Wales et al. (1998) reported an increase in herbage intake of perennial ryegrass-white clover pasture from 8 to 14.6 kg DM $cow^{-1}$ $d^{-1}$ with pasture allowances from 15 to 40 kg DM $cow^{-1}$ $d^{-1}$, however utilization decreased from 54 to 37%. The cows selected a diet 11% higher in IVDMD and 41% higher in CP concentration than that in the herbage on offer; NDF of the diet was lower than in the herbage on offer. Diet selection, facilitated by increasing herbage allowance, resulted in an increase in milk production from 9 to 15.5 kg cow$^{-1}$ d$^{-1}$, a marginal response of 0.99 kg milk kg$^{-1}$ extra DM consumed.

Supplementation of Forage Diets

There is a hierarchical order to use of nutrients, thus maintenance has priority in order to preserve the life, followed by growth, or development of structure, followed by reproduction for perpetuation of the species, and lactation to provide nourishment to the young until they can survive on they own. After these, energy present in excess of requirements for other functions may be stored as fat (Noller, 1997). The use of energy by dairy cattle depends to a large extent on the microbial fermentation that occurs in the rumen, e.g., diets that result in low ruminal acetate:propionate ratios (such as high concentrate diets) lead to increased body fat formation at the expense of milk fat synthesis (NRC, 1989).

As forage distribution within and among growth seasons is not uniform, a flexible approach to grazing management is required including adjustments of the stocking rate, maintenance of forage height and density for optimum rate of intake, and use of supplementary feeds to reduce effects of shortfalls of forage (Noller, 1997). Thus, when the quantity of pasture is limited, dairy producers need to feed stored forages, attempting to maintain more control over milk production and to improve body condition. The decision to supplement is an economic one and often based on personal preference rather than a nutritional one (Muller et al., 1995).

When energy and protein requirements increase to satisfy productive needs such as lactation, pregnancy, and growth, part of the roughage component of the diet is replaced by feeding of concentrates. This allows the ingestion of a greater amount of potential energy and protein. The concentrates present greater digestibility (75 to 90%) as compared with roughage (45 to 70%) and produce much higher fermentation rates. If adequate plant protein or NPN (non-protein nitrogen) is available, the plentiful supply of VFAs coupled with the short doubling time of the amylolytic bacteria allows high rates of microbial protein synthesis through microbe proliferation. This is subsequently reflected in a greater availability of microbial protein products of high biological value to the ruminant host.

A good rule of thumb for feeding grain on pasture is to feed one kg concentrate for each 2 kg of milk production above that supported by the pasture (Noller, 1997). A frequently used amount is 1 kg concentrate to 3.5 kg milk when lactating dairy cows grazed cool-season pastures (Burns and Bagley, 1996).

## Energy

When pastures are the major source of forage, energy is thought to be the most limiting nutrient for profitable milk production, normal reproductive performance, and weight gain (Muller et al., 1995; Noller, 1997). This is due to the low nonstructural carbohydrate (NSC) concentration of grasses (15 to 20% of DM), compared to 35 to 40% recommended for the ration of a high producing cow (Noller, 1997). Grazing cows have higher levels of activity than confined cows, and require additional energy (NRC, 1989). Cows on pasture should have their energy requirement increased 3% for every km walked per day, and to support grazing, maintenance allowances may be increased by 10% on good pastures, and up to 20% for sparse pastures (NRC, 1989). Grazing cows often have lower body condition than confined cows (Fales et al., 1995), suggesting the need for supplemental energy. Body condition of the cows in addition to the milk production level must be considered when establishing the amount of grain or supplemental energy to be fed. Thus, to counteract the more slowly digested fiber components in forages, diets of grazing animals are supplemented with energy concentrates (Noller, 1997). The main benefit from supplemental energy may be its long term effect on total milk production, body condition score, and improved reproductive performance rather than any short-term benefits (Muller et al., 1995).

Protein

Crude protein concentration of high nutritive value herbage may exceed 25%, however 65 to 85% of the protein is degradable in the rumen with 15 to 35% escaping the rumen. Escape protein may include non-protein nitrogen (NPN) such as peptides, amino acids, amines, and inorganic nitrate (Muller et al., 1995). Young grasses are often characterized by high level of NPN (Muller et al., 1995). Holden et al. (1994a) confirmed a rapid rate of rumen fermentation by dairy cows on a pasture diet relative to hay or silage. Cows fed pasture had higher ruminal ammonia and volatile fatty acids (VFA's), lower DM flow to the small intestine, and a higher bacterial N flow as a percentage of total flow. These results indicate a pre-duodenal N loss with the highly degradable N in pasture and a loss of N across the wall of the rumen. The high concentration of ammonia N in the rumen of grazing cows is in excess of microbial needs for protein synthesis. Pre-duodenal loss of N occurs when the forage contains greater than 16% CP concentration, and considering this, the duodenal protein supply may only support daily milk production of approximately 25 kg (Beever et al., 1986). The excess N is converted to urea in the liver and excreted (Muller et al., 1995). These authors stressed that N excretion is an energy requiring process, and that the excreted N will be volatilized or contribute to nitrate leaching, thus may negatively impact on the environment.

Microbial protein is the primary protein source for lactating dairy cows, therefore, optimizing microbial protein synthesis is essential. Non-structural carbohydrate is needed to utilize the pasture N, to reduce the energy cost of excreting N, and to increase supply of nutrients available to the small intestine. The lower flow of N to the small intestine suggests that increasing supplemental rumen undegradable protein (RUP) may be beneficial. The milk yield response to RUP has been variable and may be related to relatively low milk production levels in most studies (Kellaway and Porta, 1993). Muller et al. (1995) described a recent study where multiparous high producing cows (35 kg milk $d^{-1}$) responded to a higher RUP with a higher milk protein yield during early spring grazing. Supplementation of protein resistant to degradation in the rumen has been beneficial for cows fed high quality pasture (Muller et al., 1995). A summary of blood urea nitrogen (BUN) values from several Pennsylvania State University studies (Hoffman et al., 1993; Holden et al., 1994a; Fales et al. 1995) suggests an apparent excess of N in the rumen in relation to carbohydrates and a wastage of the highly degradable N in pasture forage. Values in these studies ranged from 18.5 to 28.6 mg $dl^{-1}$.

Energy protein

Extensive research has focused on increasing carbohydrate availability in the rumen to increase microbial growth and digestion (Hoover and Stokes, 1991; Nocek and Russell, 1988) and to increase protein to the small intestine (Muller et al., 1995). Under non-grazing conditions, maximum DM digestion, microbial efficiency, and protein yields were achieved when diets contained 10 to 13% degradable protein and 56% of total carbohydrate was nonstructural carbohydrate (Hoover and Stokes, 1991). In grazing situation, few studies have analyzed these concepts. Holden et al. (1994b), using the Cornell Net Carbohydrate Protein System (CNCPS) that provides a mechanism to evaluate both protein and carbohydrate, compared grass only (orchardgrass with 24.3% CP, 45% soluble protein, 43% NDF, and 25% non fiber carbohydrate, NFC), grass with 7.6 kg energy supplement (35% of ration as dry ground shelled corn), grass with 0.36 kg of bypass protein supplement (50.50 mix of fishmeal and blood meal), and grass with both the energy and protein supplement to feed a 600-kg Holstein cow in early lactation. Intake was maintained at 3.7% BW (22 kg DM $cow^{-1}$ $d^{-1}$). Milk yield increased from about 25 kg $cow^{-1}$ $d^{-1}$ on grass only and bypass protein supplement to about 35 kg $cow^{-1}$ $d^{-1}$ on energy or both energy and protein supplement. All diets exceeded the minimum required NDF and CP.

High producing cows that are grazed on high quality pasture may respond to supplemental energy and bypass protein. Response to energy and bypass protein supplement will vary depending on milk production level, stage of lactation, and quality of pasture (Combs, 1997). However, more research and information is necessary to define economics limits for supplementation (marginal returns to supplementation) and on the interaction of nutritionally balanced supplements with pasture systems (Muller et al., 1995, Combs, 1997).

## Interactions or Associative Effects between Forage and Grains

Associative effects refer to interactions among ingredients in mixed diets. These interactions result in an observed rate of animal performance that is either greater or less than expected from the sum of the individual ingredients (Moore, 1992, Moore et al., 1997). Different intake of metabolizable energy (ME) when forages and grains are fed together to ruminants is due to digestive and metabolic interactions (Dixon and Stockdale 1999). When the forages are offered free-choice and supplemental concentrates are offered in restricted amounts, forage intake may either increase, decrease, or not change (Moore, 1992). Changes in forage intake (substitution effects) may be a consequence of changes in the rate of digestion of the fibrous components (Moore, 1994, Dixon and Stockdale, 1999). Associative effects can be positive or negative (Dixon and Stockdale, 1999).

Negative associative effects (substitution) are likely to be caused by changes in rumen capacity, passage, and rate of forage fiber digestion (Dixon and Stockdale, 1999). Low rumen pH and/or insufficient supply of essential substrates for rumen microorganisms may reduce rate of fiber digestion. Negative associative effects can be minimized by supply of essential microbial substrates, feeding management, and modification of grain to reduce effects on fiber digestion, i.e., ensuring adequate digestion of the grain and satisfactory microbial protein production (Dixon and Stockdale, 1999). When forage of low digestibility is supplemented with grain-based concentrates (cereal and/or legumes), resulting intake of forage and total DM and ME may increase. These positive associative effects can be attributed to addition of a limiting forage nutrient such as, N, P, or S in these supplement, rather than due to readily fermentable carbohydrate (Dixon and

Stockdale, 1999). Consequently, it may be most cost-effective to provide inorganic microbial substrates rather than grain-based supplement.

Usually forage intake will be decreased by concentrates when forage quality is high, other nutrients are in balance with energy, and concentrates are fed in large amounts, however when forages are low in quality, and small amounts of concentrates are fed, voluntary intake may increase (Moore, 1994). Substitution rates are often low when animals are consuming forage of low to medium digestibility, however they are generally high when ruminants are consuming a high amount of forage of high digestibility, probably due to the metabolic mechanisms which control voluntary intake reducing forage intake (Dixon and Stockdale, 1999).

Moore (1994) suggests that a special case of substitution and associative effects is the use of TMRs, especially for lactating dairy cows. Such diets may include several forages and combinations of both energy and protein concentrates. Because TMRs often are based on high quality forages and include high percentages of concentrates, intake and digestibility of the forage component is very likely less than that expected when forage is fed alone. In such cases, complex models such as the Cornell model may be necessary to predict animal performance accurately, but they must consider the effects of concentrates on forage intake and digestibility.

The amount of supplemental energy fed can have long term effects on energy balance and in turn on milk production, body weight and condition changes, and on reproductive performance (Muller et al., 1995). The long term effects of supplemental energy are usually greater than the short term (Kellaway and Porta, 1993). The response in milk production is based on the energy density of supplement and increased DM intake, but it also may be related to the stage of lactation and milk yield, body condition, and the substitution effect.

Substitution rate

In general, the decrease in herbage intake is less than the increase in grain intake, resulting in greater total DM intake (Kellaway and Porta, 1993). Substitution rates of grain for pasture vary, but usually pasture DM intake decreases about 0.5 to 0.9 kg for each kg of grain fed and this substitution rate may be associated with increased acidity in the rumen and may be greater when starchy supplements are fed (Muller et al., 1995).

Meijs and Hoekstra (1984) at Netherlands reported mean substitution rates of perennial ryegrass herbage by concentrates of 0.1 and 0.5 kg herbage OM kg$^{-1}$ concentrate OM at the low and high herbage allowance (16 and 24 kg OM cow$^{-1}$ d$^{-1}$). Meijs (1986) reported that substitution rate of ryegrass herbage with allowance of 28 kg OM cow$^{-1}$ d$^{-1}$ was reduced from 0.45 kg herbage OM kg$^{-1}$ of high-starch concentrate (5.4 kg OM cow$^{-1}$ d$^{-1}$ of high-starch concentrate and 11.5 kg OM cow$^{-1}$ d$^{-1}$ herbage intake) to 0.21 kg herbage OM kg$^{-1}$ of high-fiber concentrates (5.3 kg OM cow$^{-1}$ d$^{-1}$ of high-fiber concentrates and 12.6 kg OM cow$^{-1}$ d$^{-1}$). Daily liveweight gain was 0.17 kg greater with high-starch concentrates than with the high-fiber concentrate, however daily milk yield was 1.8 kg cow$^{-1}$ higher for the high-fiber concentrate. Robaina et al. (1998) in Australia reported substitution rates of 0.3 and 0.6 kg of herbage of perennial ryegrass and white clover per kg grain DM consumed (5 kg of a 70:30 mixture of barley and lupins) at the low and high herbage allowances (20 and 40 kg DM cow d$^{-1}$), respectively. These authors also reported another experiment using 0, 1.8, 3.4, and 6.7 kg barley cow$^{-1}$ d$^{-1}$ when higher grain intake resulted in greater yields of milk, fat, protein, and lactose. Milk responses diminished from 1.6 to 0.8 kg milk kg$^{-1}$ barley at highest barley intake. The authors suggested that higher level of substitution and less efficient use of grain contributed to the poorer production responses at higher levels of grain feeding.

Kellaway and Porta (1993) suggested that differences between grain sources may be more important at a higher level of grain feeding. For instance, when cows are grazing high quality, low fiber pastures in the spring, there may be advantages to including a digestible fiber source such as soy hulls, wheat mids, corn gluten feed, or beet pulp. Van Vuuren et al. (1993) compared high-starch concentrates to high-fiber concentrates, and did not find milk production differences. Starch feeding increased milk protein and decreased milk fat as compared to feeding fibrous concentrate. Reis (1998) reported an increase in milk yield, solids corrected milk, milk protein and solids non-fat concentration with increasing amounts of a ground-corn based concentrate, however he reported that MUN (milk urea concentration) and milk fat decreased linearly with supplementation. Although intake and digestibility of DM and OM increased as grain supplementation was increased, forage OM intake decreased.

### Heat Stress

The most successful approach to feed intake prediction has been to recognize environmental factors affecting feed intake, for instance heat stress reduces intake, while cold may promote it, and integrate them into a system that also considers the physiological state of the animal, whether lactating, growing, or under environmental stresses (Williams et al. 1993, Van Soest, 1994). When temperature rises above the lower critical temperature, the animal maintains its body temperature and increases its heat loss by simple mechanisms, such as stopping huddling, changing posture to allow more contact with cooler surfaces, and dilating peripheral blood vessels. With further increases above the evaporative critical temperature, the animal reduces its heat production by decreasing voluntary intake and milk production (Williams et al., 1993).

Beede and Collier (1986) reported that feed intake of confined lactating dairy cows begins to decrease at mean daily environmental temperatures of 25 to 27°C. In tropical conditions the grazing time of milking cows is reduced to a maximum 7.5 h from afternoon to morning, compared to 10 h in cool weather (Beede and Collier, 1986). As energy intake decreases, the requirements of energy for maintenance of heat-stressed animals is increased. The addition of fat to the diet of heat-stressed animals is strategic because fat supplements have a low heat of metabolism and are not fermented in the rumen. Reduction of dietary protein levels avoids generation of heat in catabolic pathways, and the reduction of amount of forage fed decreases heat of fermentation. Low temperatures may increase feed intake 30%, on the other hand muddy conditions may depress feed intake by an equal amount. Exposure of animals to precipitation, wind, and low temperature potentially increase heat loss and may require additional energy.

Moe et al. (1971) found the maintenance requirement of lactating cows to be 73 Kcal of NEL $kg^{-0.75}$ of liveweight. An additional 10% should be added for activity, reaching 80 Kcal of NEL $kg^{-0.75}$ of liveweight. To support grazing, maintenance allowances may be increased by 10% for good pasture and up to 20% for sparse pasture (NRC, 1989). Cows eat more feed to support greater milk production, thus a smaller portion of feed energy intake is partitioned toward meeting maintenance needs, and a greater portion is directly transferred to milk.

### Body Reserves

Milk production uses body energy with an efficiency of 82%. The amount of NEL spared by the loss of 1 kg of body tissue is (6.00 * 0.82) = 4.92 Mcal. If the efficiencies of ME used for milk production and body gain by lactating animals are 64 and 75%, respectively, the amount of NEL required for 1 kg of tissue gain during lactation is (6.00) (0.64/0.75) = 5.12 Mcal (NRC, 1989). Moe et al. (1971) affirmed that replacement of body tissue energy may be more efficient while the cow is lactating than when dry, however care must be exercised to avoid over-fattening. In practice, most cows lose some weight during the first few weeks of lactation and then shift to a relatively small but positive balance for the rest of lactation (NRC, 1989).

# CHAPTER 3
# FORAGE DISTRIBUTION AND NUTRITIVE VALUE OF INTENSIVELY MANAGED PEARL MILLET AND SORGHUM-SUDANGRASS

## Introduction

Pearl millet (*Pennisetum glaucum* [L.] R. BR.) and sorghum-sudangrass (*Sorghum bicolor* [L.] Moench) originated in Africa. They are important crops for human nutrition in India, Pakistan, and several countries of Africa. Pearl millet is grown as a food cereal on some 26 million ha (FAO, 1990). The major use of pearl millet in the USA, South America, and Australia is as a fodder crop, specifically for grazing and silage for livestock (Andrews and Rajewski, 1995).

These species are annuals, erect, 0.5- to 5-m tall, leafy, drought tolerant, and responsive to N. Their forage nutritive value is high when harvested at an immature stage. Yields are also high, but over a short season. These species are valuable in the development of year-round forage systems where forage quality is important, such as with lactating dairy cows or rapidly growing animals (Fribourg, 1995).

According to USDA statistics, between 1953 and 1978 average annual milk yield cow$^{-1}$ increased from 2300 to 5100 kg, whereas the annual intake feed units (TDN x 0.786) on average increased from 2400 and 5290 kg cow$^{-1}$. Of this total, concentrates, hay, other harvested forage, and pasture contributed 28, 24, 17, and 31% in 1953, and 43, 18, 19, and 20% in 1978 (Waldo and Jorgensen, 1981). Therefore producers dramatically reduced pasture utilization, replacing it primarily with concentrate.

In recent years, the dairy industry is facing a profit squeeze, and this scenario makes home-grown feeds and grazed forage more attractive. Pasture-based dairies have much lower start-up costs for housing, waste-handling facilities, and harvesting/feeding equipment. Pastures may reduce the feed costs. They generally provide the cheapest source of nutrients, because grazing with cattle reduces cost and eliminates losses of nutrients associated with harvesting, processing, storing, and feeding of crops. Another benefit of grazing is that nutrients in livestock waste are deposited directly on the pasture and are recycled to produce more forage. This aspect plus the greater visual appeal of pasture-based compared with confinement dairies may improve public perception of the industry.

Although perennial pastures usually are the most economical sources of feed, warm-season perennial grasses are relatively low in digestible energy and high in fiber, especially in late summer and fall. To attain higher milk production, higher nutritive value forages are needed. Warm-season annual grasses may fit these production systems. In addition, planting pastures at different planting dates may reduce the risk of encountering undesirable environments for establishment and improve forage distribution with superior nutritive value.

With the intent of assessing the potential of warm-season annual grasses for pasture-based dairies, research is needed that describes seasonal dry matter (DM) distribution and nutritive value of these grasses when managed intensively. The purpose of this trial was to compare seasonal DM distribution of pearl millet and sorghum-sudangrass genotypes planted at different dates, harvested frequently, and fertilized liberally.

## Materials and Methods

The experiments were done in 1996 and 1997 at the Beef Research Unit (BRU) approximately 24 km northeast of Gainesville, FL. Soils belonged to the Plummer (loamy, siliceous, thermic Grossarenic Paleudults) and Sparr series (loamy, siliceous, hyperthermic Ultic Haplaquods, USDA, 1985). Mean soil pH of experimental sites was 6.4, and Mehlich I extractable P and K averaged 18 and 37 mg $kg^{-1}$, respectively.

The treatments were genotypes and 3-wk interval planting dates. The genotypes were three pearl millets ('GK 600', 'Millex 32', and 'Tifleaf 2'), and two sorghum-sudangrasses ('Hygrazer', and 'SX 15'). Planting dates were 10 and 31 May, 21 June, and 12 July in 1996, and 20 March, 10 April, 1 and 22 May, 10 June, and 1 July in 1997. Treatments were arranged in a split-plot experiment as a randomized complete block design with four replications. Planting date was the main plot factor and genotype the sub-plot.

The response variables measured were total-season DM yield, DM yield by harvest, leaf percentage, and nutritive value as described by crude protein (CP) and in vitro organic matter digestion (IVOMD) of total herbage, leaf, and culm components.

Fertilization was applied at rates of 200, 18, and 66 kg $ha^{-1}$ $yr^{-1}$ of N, P, and K, respectively. The total P and K and 40 kg N $ha^{-1}$ were applied 1 wk after planting. The remaining N was split in four equal applications (40 kg N $ha^{-1}$ each) after the first four harvests of each planting date. Irrigation was used as needed to ensure stand establishment.

Weed control in 1996 was done by hand throughout the season. In 1997, to control Florida pusley (*Richardia scabra* L.) dicamba (1.17 L $ha^{-1}$) was applied. Southern sandspur (*Cenchrus echinatus* L.) was present in the area as well.

The subplot unit size in 1996 was 8.1 $m^2$ (six rows x 4.5 m x 0.3 m) and the sampling unit size was 3.6 $m^2$ (four rows x 3 m x 0.3 m). In 1997, the subplot was 16.8 $m^2$ (seven rows x 8 m x 0.3 m), and the sampling unit size was 6.3 $m^2$ (three rows x 7 m x 0.3 m).

The plants were clipped when 50- to 60-cm tall to a 10-cm stubble using a sickle-bar mower. Harvests were every 2 to 4 wk for a total of four to eight harvests, i.e., the first planting date was harvested eight times and the last planting date four times.

In each harvest, two samples were taken per genotype, one of about 0.5 kg to dry immediately, and the other of about 0.2 kg to separate by hand in to leaf (blade) and culm (culm plus sheath). These samples were used to estimate CP and IVOMD of total herbage, leaf, and culm. After drying, the samples were ground to pass a 1-mm screen using a Wiley mill and analyzed for N and IVOMD. Samples were digested for N determinations using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Ammonia in the digestate was determined by semiautomatic colorimetry (Hambleton, 1977). The CP (DM basis) was calculated as N x 6.25. The IVOMD concentration was determined using the two-stage procedure (Tilley and Terry, 1963) modified by Moore and Mott (1974). The donor cow was fed a diet of bermudagrass (*Cynodon dactylon* [L.] Pers.) hay.

The statistical analysis used was analysis of variance using planting dates, genotypes, and their interaction as fixed effects. Repeated measures analysis of variance was used to assess harvest date effects for each response variable using the SAS system for Mixed Models (Littell et al., 1996; Littell et al., 1998; SAS Institute, 1989). Differences were considered to be significant at $P < 0.05$. Means were separated using the least significant difference (LSD) test in SAS system (SAS Institute, 1989). Linear regression analysis were performed using planting date (1 to 6) and harvest order (1 to 7) as independent variables and responses as dependent variables. The general polynomial model was

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_1^2 + \ldots + \beta_k x_1^k + \varepsilon$$

The value of the coefficient of determination ($R^2$), a measure of the fraction of total variance explained by the regression, was calculated using treatment averages of each response variable.

## Results and Discussion

### Forage Yield

### Total annual DM yield

There was no genotype by planting date interaction ($P = 0.1923$) for total DM yield in 1996, but interaction did occur ($P = 0.0001$) in 1997 (Table 3.1). Across genotypes, forage yield decreased linearly at a rate of 25 to 30 kg DM $ha^{-1}$ $d^{-1}$ (Fig. 3.1) for each day planting date was delayed in 1996. In 1997 plantings, forage yield also decreased linearly at a rate of 23 to 36 kg DM $ha^{-1}$ $d^{-1}$ (Fig. 3.1) for all genotypes, except

Table 3.1 Probability levels (F test) for the planting date (PD), genotype (G), G x PD, and G x harvest effects on total dry matter yield, dry matter yield per harvest, leaf percentage, and nutritive value for total herbage harvested, leaf (blade), and culm (culm plus sheath) of pearl millet and sorghum-sudangrass genotypes planted at four and six planting dates in 1996 and 1997, respectively

| Source†<br>1996 | df‡ | Total DM yield | DM per harvest | Leaf (%) | CP (%) | IVOMD (%) | Leaf CP (%) | Leaf IVOMD (%) | Culm CP (%) | Culm IVOMD (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| Planting date (PD) | 3 | 0.0006§ | 0.1216 | 0.0001 | 0.0001 | 0.0002 | 0.0001 | 0.0001 | 0.0414 | 0.0019 |
| Genotype ( G ) | 4 | 0.0108 | 0.0121 | 0.7136 | 0.1741 | 0.4534 | 0.1869 | 0.0008 | 0.3208 | 0.4486 |
| G x PD | 12 | 0.1923 | 0.0755 | 0.8753 | 0.9991 | 0.5719 | 0.9988 | 0.4463 | 1.0000 | 0.7398 |
| G x Harvest | 35 | - | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0395 | 0.3355 |
| 1997 | | | | | | | | | | |
| Planting date (PD) | 5 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.4167 | 0.0001 | 0.0175 | 0.0001 | 0.6867 |
| Genotype ( G ) | 4 | 0.0001 | 0.0002 | 0.0001 | 0.0441 | 0.3835 | 0.0549 | 0.0003 | 0.0077 | 0.0001 |
| G x PD | 20 | 0.0001 | 0.3335 | 0.0272 | 0.6838 | 0.5856 | 0.8475 | 0.2339 | 0.5048 | 0.9509 |
| G x Harvest | 31 | - | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0001 | 0.0010 | 0.0273 |

† Planting date by harvest and the three-way interaction were not estimable because of missing values due to differing numbers of harvests for the different planting dates

‡ Degrees of freedom

§ Pr > F

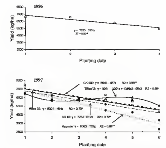

Figure 3 1 Planting date (PD) effect on total dry matter yield of pearl millet and sorghum-sudangrass genotypes in 1996 and 1997 1996-PD 1 (10 May), 2 (31 May), 3 (21 June), 4 (12 July), and 1997-PD 1 (20 March), 2 (10 April), 3 (1 May), 4 (21 May), 5 (10 June), and 6 (1 July) Data points in 1996 are LSmeans across five genotypes and four replicates, in 1997 they are LSmeans across four replicates * P < 0 05 **P < 0 01

Tifleaf 2 millet. Tifleaf 2 tended to maintain forage yield from March to June plantings (Fig. 3.1 and Table 3.2).

Causley (1990) in New Zealand reported greatest DM yield from February to April (summer-early fall) for sorghum-sudangrass planted in the first two plantings, although frost damage occurred in the first three plantings. Other previous research reported lower DM yield at later plantings during the early spring through summer period for annual grasses (Moomaw and Mader, 1991, Hattab and Harb, 1991, Harb and Hattab, 1991, and Mohammad, 1995). These authors attributed lower yield to summer droughts, cool fall temperatures, and short days (Fribourg, 1995). In the current experiment, with exception of Tifleaf 2 in 1997, greatest total DM yield per harvest was obtained with an early planting date for all genotypes. This result agrees with data reported by Causley (1989) in New Zealand where yield was reduced from 6000 to 2800 kg DM. ha$^{-1}$ on Sudax sorghum-sudangrass when planting was delayed from summer to early fall. On the other hand, M'Khatir and Vanderlip (1992) found no consistent effect of planting date on either pearl millet or sorghum-sudangrass in Kansas. They did find that plant population was less critical for pearl millet than for sorghum in determining final yield because of higher tillering capability of pearl millet.

There were planting date ($P = 0.0006$) and genotype effects ($P = 0.0108$) in 1996 for total DM yield (Table 3.1). Cultivar SX 15 sorghum-sudangrass tended to have greatest total DM yield, however, it was not different than Tifleaf 2 pearl millet (Table 3.2). In 1996, two of the four replicates were planted in moderately to poorly drained soils. In this environment, when rainfall is average or above average sorghums are more

Table 3.2 Genotype effect for 1996 and genotype by planting date interaction effects in 1997 on total dry matter yield of pearl millet and sorghum-sudangrass

| Genotype | 1996 avg. | 1997 Planting date 1<br>20 March | 2<br>10 April | 3<br>1 May | 4<br>22 May | 5<br>10 June | 6<br>1 July | 1997 Regression<br>x = planting date |
|---|---|---|---|---|---|---|---|---|
| | kg DM ha$^{-1}$ | | | | | | | |
| GK 600 | 6350 b | 7820 ab A† | 6740 a B | 6370 a B | 6190 ab B | 6070 ab B | 4840 a C | y = 8041 - 487 x<br>$R^2 = 0.89^{**}$ |
| Millex 32 | 5730 b | 7980 a A | 6340 a BC | 6060 a BC | 6800 a B | 5630 b C | 4810 a D | y = 8001 - 494 x<br>$R^2 = 0.73^{*}$ |
| Tifleaf 2 | 6600 ab | 6980 b A | 6110 a BC | 6250 a ABC | 6370 ab AB | 6520 a AB | 5540 a C | $y = 9261 - 3200x + 1016x^2 - 98x^3$ $R^2 = 0.98^{*}$ |
| Hygrazer | 6110 b | 7020 b A | 6200 a B | 6440 a AB | 5010 c C | 4770 c C | 2800c D | y = 8058 - 766 x<br>$R^2 = 0.88^{**}$ |
| SX 15 | 7440 a | 6980 b A | 6720 a A | 6460 a AB | 5730 b B | 6200ab AB | 3860 b C | y = 7784 - 512 x<br>$R^2 = 0.72^{*}$ |
| SE | 340 | 300 | 280 | 280 | 280 | 280 | 280 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a genotype by planting date interaction for total DM yield in 1997 ($P < 0.0001$), but not in 1996 ($P > 0.1923$).

productive than pearl millets. The soil at the experimental site in 1997 was well drained, an environment favorable to pearl millet genotypes according to Rachie and Majmudar (1980), and the millet cultivars yielded as much or much more than the sorghums for all planting dates (Table 3.2).

The interaction of genotype and planting date ($P = 0.0001$) for total DM yield in 1997 occurred because there were few or no differences among genotypes in the March, April, and early-May planting dates; however, after that, pearl millet genotypes were superior to Hygrazer sorghum-sudangrass, and in the last planting date (1 July 1997) pearl millet genotypes outyielded both sorghum genotypes. Millet genotypes GK 600 and Tifleaf 2, and sorghum SX 15 had greater yield stability among planting dates. They maintained high yields, about 6000 kg ha$^{-1}$, from March to early-June planting dates, while Millex 32 produced this yield until the late-May planting and Hygrazer maintained the same total DM yield just through the early-May planting. Although there were yield stability differences among genotypes, for all of them there was a dramatic decrease in yield for the July planting. Among the sorghums, SX 15 was superior to Hygrazer in 1996, and in the last three planting dates of 1997. Yield among millet genotypes did not differ consistently in either year.

DM yield per harvest

There was no genotype by planting date interaction for DM yield per harvest in 1996 ($P = 0.0755$) or in 1997 ($P = 0.3335$, Table 3.1). There also was no effect of planting date in 1996 ($P = 0.1216$), but in 1997 the March planting date yielded more DM per harvest than later planting dates (Table 3.3).

Table 3.3 Planting date effects on dry matter yield per harvest of pearl millet and sorghum-sudangrass genotypes planted at four and six planting dates in 1996 and 1997, respectively. Number of harvests ranged from four to eight depending on planting date.

| Planting date | 1996 | 1997 |
|---|---|---|
| | kg DM $\text{ha}^{-1}$ | |
| Late-March | - | 1040 a |
| Early-April | - | 900 b |
| Early-May | 890 a† | 920 b |
| Late-May | 920 a | 900 b |
| Early-June | 850 a | 930 b |
| Early-July | 1050 a | 700 c |
| SE | 83 | 33 |

† Values within a column followed by the same letter are not different ($P > 0.05$) by LSD. There was no genotype by planting date interaction in 1996 ($P > 0.0755$) or 1997 ($P > 0.3335$).

There was a genotype by harvest interaction ($P = 0.0001$) in both years (Table 3.1). The DM yield per harvest decreased from about 1500 kg DM $\text{ha}^{-1}$ in the second harvest to about 400 kg DM $\text{ha}^{-1}$ at the seventh harvest (Tables 3.4 and 3.5). It represented an average reduction of about 150 to 200 kg DM $\text{ha}^{-1}$ per harvest, from the first to seventh harvest. After the third or fourth harvest, increasing tiller death was observed, likely due to removal of apical meristems. The reduction of live tillers was a result of harvesting to a 10-cm stubble height frequently, i.e., every 2 to 4 wk.

Table 3 4. Genotype by harvest interaction effects on dry matter yield per harvest of pearl millet and sorghum-sudangrass genotypes planted at four planting dates in 1996

| Genotype | Harvest | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | kg DM ha$^{-1}$ | | | | | | | |
| GK 600 | 890 b BC† | 1500 a A | 1310 a AB | 1060 ab BC | 1000 a BC | 770 a CD | 320 a D | 220 a D |
| Millex 32 | 1050 ab B | 1660 a A | 990 a B | 860 b B | 840 a B | 690 a BC | 300 a C | 210 a C |
| Tifleaf 2 | 820 b C | 1640 a A | 1330 a AB | 1050 ab BC | 1180 a C | 700 a C | 430 a C | 170 a D |
| Hygrazer | 1160 ab AB | 1520 a A | 1120 a B | 970 b BC | 940 a BC | 680 a CD | 340 a D | 260 a D |
| SX15 | 1310 a AB | 1680 a A | 1290 a B | 1380 a AB | 1300 a AB | 960 a BC | 610 a CD | 580 a D |
| SE | 154 | 154 | 154 | 154 | 178 | 179 | 218 | 304 |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different (P > 0 05) by LSD There was a genotype by harvest interaction in 1996 (P < 0 0001)

Table 3.5 Dry matter yield per harvest of pearl millet and sorghum-sudangrass genotypes planted at six planting dates in 1997

| Genotype | Harvest | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | | | | kg DM ha$^{-1}$ | | | |
| GK 600 | 1310 b A† | 1400 a A | 1170 a AB | 1020 a BC | 790 a CD | 580 a DE | 380 a E |
| Millex 32 | 1720 a A | 1070 b B | 1140 a BC | 1020 a CD | 730 a D | 660 a D | 390 a D |
| Tifleaf 2 | 920 c BC | 1480 a A | 1270 a AB | 1150 a B | 860 a C | 610 a CD | 410 a D |
| Hygrazer | 1210 b A | 780 c BC | 1070 a AB | 970 a BC | 670 a C | 560 a CD | 320 a D |
| SX 15 | 1260 b A | 850 bc BC | 1180 a AB | 1040 a BC | 790 a BC | 620 a CD | 450 a D |
| SE | 85 | 85 | 85 | 85 | 85 | 95 | 155 |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a genotype by harvest interaction in 1997 ($P < 0.0001$)

Cumulative DM yield of the first four harvests represented 66% of total annual DM yield in 1996 and 72% in 1997 Cultivar SX 15 sudangrass presented greater DM yield per harvest than GK 600 and Tifleaf 2 pearl millets in the first harvest of 1996, but in the second year, Millex 32 pearl millet had greatest first-harvest yield. However, genotype did not affect yield in most harvests, and no differences occurred after the fourth harvest in 1996 (Table 3.4) and after the second in 1997 (Table 3.5) Genotypes of both species had greatest yield in the first two or three harvests Millex 32 presented the highest yield in just the first harvest after each planting, and immediately thereafter reduced yield, probably due to its early maturity and the associated greater damage from cutting

Yield generally was above 1000 kg DM $ha^{-1}$ from the first to fourth or fifth harvest which is a reasonable herbage mass for steer grazing (Coser and Maraschin, 1983, Josifovich and Ceressetto, 1989) Reduction of regrowth vigor after several cuttings could be attributed to abiotic factors and to stage of plant development, type of tissue removed during harvests organic reserves, tiller number, and the timing of apical meristem removal (Richards, 1993, Chapman and Lemaire, 1993) In the present case, almost all young tissue was removed every harvest leaving reduced leaf area and perhaps low organic reserves due to high harvest frequency

### Herbage yield per growth period and growth rate

When considering their use in production systems, seasonal growth rates and herbage distribution of warm-season annuals are critical. There were genotype by growth period and planting date by growth period interactions for herbage yield per growth period in both years (P = 0.0001, Tables 3.6 to 3.9) Summer had the greatest herbage yield per growth period There were no differences in DM yield per growth period among

Table 3 6 Genotype by growth period interaction effects on dry matter yield per growth period of pearl millet and sorghum-sudangrass planted at four planting dates in 1996

| Genotype | Growth period<br>Spring<br>(before 21 June) | <br>Summer<br>(22 June to 21 September) | <br>Fall<br>(after 21 September) |
|---|---|---|---|
| | ---------- kg DM $ha^{-1}$ | ---------- | ---------- |
| GK 600 | 810 a C† | 3340 b A | 2260 ab B |
| Millex 32 | 680 a C | 3310 b A | 1780 ab B |
| Tifleaf 2 | 840 a C | 3340 b A | 2420 a B |
| Hygrazer | 520 a C | 3970 b A | 1620 b B |
| SX15 | 580 a C | 4350 a A | 2510 a B |
| SE | 272 | | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD There was a genotype by growth period interaction in 1996 ($P < 0.0001$)

Table 3.7 Genotype by growth period interaction effects on dry matter yield per growth period of pearl millet and sorghum-sudangrass planted at six planting dates in 1997

| Genotype | Growth period | | |
|---|---|---|---|
| | Spring<br>(before 21 June) | Summer<br>(22 June to 21 September) | Fall<br>(after 21 September) |
| | kg DM ha$^{-1}$ | | |
| GK 600 | 1090 a B† | 4940 a A | 310 a C |
| Millex 32 | 1130 a B | 4850 a A | 250 a C |
| Tifleaf 2 | 830 a B | 5110 a A | 360 a C |
| Hygrazer | 940 a B | 4220 b A | 240 a C |
| SX15 | 880 a B | 4710 a A | 400 a C |
| SE | 168 | | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a genotype by growth period interaction in 1997 ($P < 0.0001$).

Table 3 8 Planting date by growth period interaction effects on dry matter yield per growth period of pearl millet and sorghum-sudangrass in 1996

| Planting date | Growth period |  |  |
|---|---|---|---|
|  | Spring<br>(before 21 June) | Summer<br>(22 June to 21 September) | Fall<br>(after 21 September) |
|  | kg DM ha$^{-1}$ |  |  |
| 10 May | 2730 A† | 2540 c A | 1830 b B |
| 31 May | - | 4580 a A | 2490 a B |
| 21 June | - | 3650 b A | 2640 a B |
| 12 July | - | 3890 b A | 1520 b B |
| SE | 189 |  |  |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0 05$) by LSD There was a planting date by growth period interaction in 1996 ($P < 0 0001$)

Table 3.9 Planting date by growth period interaction effects on dry matter yield per growth period of pearl millet and sorghum-sudangrass in 1997.

| Planting date | Growth period | | |
|---|---|---|---|
| | Spring (before 21 June) | Summer (22 June to 21 September) | Fall (after 21 September) |
| | ---------------------------- | kg DM ha$^{-1}$ | ---------------------------- |
| 20 March | 2860 a B† | 4450 c A | - |
| 10 April | 1580 b B | 4780 b A | 450 b C |
| 1 May | 1400 b B | 4910 b A | - |
| 22 May | - | 5310 a A | 560 ab B |
| 10 June | - | 5610 a A | 290 b B |
| 1 July | - | 3520 d A | 670 a B |
| SE | 172 | 172 | 230 |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a planting date by growth period interaction in 1997 ($P = 0.0001$).

genotypes in spring of both years and in fall of 1997 (Tables 3.6 and 3.7). During fall 1996, SX 15 sorghum and Tifleaf 2 millet had greater yield than Hygrazer sorghum (Table 3.6). Yield of sorghums in summer was likely the main reason for interaction as SX 15 sorghum had the greatest yield in summer 1996 (Table 3.6) and Hygrazer had the lowest yield in summer 1997 (Table 3.7). Planting dates after early May did not produce any harvested DM yield during spring (Tables 3.8 and 3.9). In 1996, the greatest DM yield in fall was for late May and June plantings (Table 3.8), while in fall 1997, the July planting had, or tended to have, the greatest DM yield (Table 3.9).

Growth rate data are one means of assessing the impact of planting dates on seasonal distribution of DM. To simplify presentation, growth rate data are shown for only three planting dates in each year (Figs. 3.2 and 3.3). Each curve represents the average of the five genotypes for a given planting date. For both years, the highest daily growth rate of 100 to 115 kg DM ha$^{-1}$ d$^{-1}$ occurred with the earliest planting date, during late spring and early summer. Even though later planting dates also presented high maximum growth rates, about 80 kg DM ha$^{-1}$ d$^{-1}$, these rates occurred during a very short period of approximately 1 mo. For the 10 May 1996 and 10 Apr. 1997 planting dates, growth rates of one-half of maximum (50-60 kg DM ha$^{-1}$ d$^{-1}$) lasted for about 7 to 8 wk. The high yield potential for both species is well known, but the question is how can forage distribution be improved across the growing season. One reasonable alternative may be through use of at least two planting dates with a 3- to 5-wk interval between plantings. Based on 1996 data (Fig. 3.2) combining the 10 May with either 31 May or 12 July dates was sufficient to maintain growth rate above 30 kg DM ha$^{-1}$ d$^{-1}$ until the middle

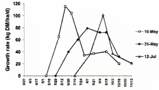

Figure 3.2 Average growth rate of three pearl millet and two sorghum-sudangrass genotypes planted at three dates in 1996

of October The response was similar in 1997 (Fig. 3.3), although the yield response for the 22 May date was not as great nor as long lasting as for 31 May 1996 These data suggest that forage distribution may be improved and the autumn forage deficit reduced by planting pearl millet and or sorghum-sudangrass genotypes at two or more dates and utilizing intensive management including frequent harvests

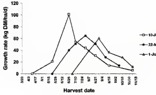

Figure 3.3 Average growth rate of three pearl millet and two sorghum-sudangrass genotypes planted at three dates in 1997

Leaf percentage

The management used prioritized forage nutritive value instead of quantity. There was no planting date by genotype interaction for leaf percentage in 1996 (P = 0.8753), but this interaction did occur in 1997 (P = 0.0272, Table 3.1). Also, there were no differences among genotypes in 1996 (P = 0.7136) when the annual average leaf percentage ranged from 70 to 75%. In 1997, Tifleaf 2 pearl millet had the highest leaf percentage for the March to June planting dates, except for early April when it did not differ from GK 600 millet. For the July planting date Millex 32 pearl millet had the lowest leaf percentage

(Table 3 10) On average, Hygrazer sorghum had intermediate leafiness, about 75%, while SX 15 sorghum and Millex 32 were less leafy, but still high with close to 70% of leaf in total DM produced Mulcahy and Stuart (1987) tested forage sorghum cultivars and found leaf:culm ratio ranging from 2.2 for Magic, a late maturing cultivar, to 0.57 for Trudan and 0 43 for Piper On the other hand, Gahi-1 pearl millet when cut at a 50-cm height to a 25-cm stubble yielded 14,000 kg DM $ha^{-1}$ containing 90% leaf (Fribourg, 1995)

There was a planting date effect on leaf percentage in 1996, average leaf percentage across harvests decreased linearly as planting date was delayed (Fig 3 4) The planting date by genotype interaction in 1997 occurred due to an atypical response of SX 15 sorghum. It had lower leaf percentage in late March than in early April plantings and it increased leaf percentage for early June to early July plantings while the other cultivars maintained or decreased leaf percentage at later dates (Table 3 10 and Fig 3 4) Forage from dwarf pearl millet had higher leaf percentage than forage from tall plants (Hanna et al. 1979) The dwarf types had reduced internode length, plant height, and culm percentage (Burton and Fortson, 1966) Differences in forage nutritive value between dwarf and tall genotypes were generally found to be greater at late stages of growth (Burton et al., 1969)

There were genotype by harvest interactions on leaf percentage (P = 0 0001) in both years (Table 3 1) Tifleaf 2 pearl millet had as great or greater percentage than the other genotypes independent of harvest in both years (Tables 3 11 and 3 12) There were no differences in leaf percentage between sorghum genotypes in either year, and among

Table 3.10. Genotype by planting date interaction effects on leaf percentage of pearl millet and sorghum-sudangrass genotypes planted at six dates in 1997.

| Genotype | Planting date<br>1<br>20 Mar | <br>2<br>10 Apr | <br>3<br>1 May | <br>4<br>22 May | <br>5<br>10 June | <br>6<br>1 July | 1997 Regression<br>x = planting date |
|---|---|---|---|---|---|---|---|
| | | | | % | | | |
| GK 600 | 84 b A† | 86 a A | 85 b A | 80 b A | 77 b B | 70 a B | $y = 81.7 + 3.8x - 0.95x^2$<br>$R^2 = 0.98^*$ |
| Millex 32 | 75 c A | 73 b AB | 72 c AB | 67 c BC | 63 c CD | 53 b D | $y = 81.7 - 4.1x$<br>$R^2 = 0.89^{**}$ |
| Tifleaf 2 | 92 a A | 91 a A | 94 a A | 89 a A | 84 a B | 74 a C | $y = 98.9 - 3.3x$<br>$R^2 = 0.71^*$ |
| Hygrazer | 80 b A | 76 b AB | 78 c A | 72 c B | 71 b B | 72 a B | $y = 80.9 - 1.74x$<br>$R^2 = 0.77^*$ |
| SX 15 | 67 c BC | 76 b A | 73 c AB | 69 c B | 63 c C | 68 a B | $y = 42 + 36x - 11.5x^2 + 1.04x^3$<br>$R^2 = 0.97^*$ |
| SE | 2.4 | 2.4 | 2.5 | 2.7 | 2.8 | 2.9 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a genotype by planting date interaction for leaf percentage in 1997 ($P < 0.0272$). $^*P < 0.05$ $^{**}P < 0.01$

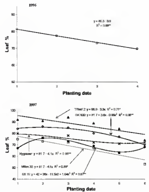

Figure 3 4 Planting date effect on leaf percentage of pearl millet and sorghum-sudangrass genotypes in 1996 and 1997 1996-PD 1 (10 May), 2 (31 May), 3 (21 June), 4 (12 July) and 1997-PD 1 (20 March), 2 (10 April), 3 (1 May), 4 (22 May), 5 (10 June), and 6 (1 July) Data points in 1996 are LSmeans across five genotypes and four replicates, in 1997 they are LSmeans across four replicates

Table 3.11. Genotype by harvest interaction effects on leaf percentage of pearl millet and sorghum-sudangrass genotypes planted at four planting dates in 1996

| Genotype | Harvest | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | % | | | | | | | |
| GK 600 | 84 ab A† | 76 a ABC | 81 a AB | 77 a ABC | 72 a BC | 71 a BC | 64 ab C | 62 a C |
| Millex 32 | 76 b AB | 77 a AB | 79 a A | 66 a B | 72 a AB | 75 a AB | 77 a AB | 70 a AB |
| Tifleaf 2 | 84 ab A | 80 a AB | 79 a AB | 71 a B | 71 a B | 69 a B | 71 ab B | 70 a AB |
| Hygrazer | 87 a A | 79 a AB | 78 a AB | 70 a B | 73 a B | 72 a B | 71 ab B | 63 a AB |
| SX 15 | 86 ab A | 71 a B | 86 a A | 71 a B | 66 a B | 66 a B | 59 b B | 60 a B |
| SE | 3.8 | 3.8 | 3.8 | 3.8 | 4.4 | 4.5 | 5.6 | 7.9 |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a genotype by harvest interaction for leaf percentage in 1996 ($P < 0.0001$).

Table 3.12 Genotype by harvest interaction effects on leaf percentage of pearl millet and sorghum-sudangrass genotypes planted at six planting dates in 1997

| Genotype | Harvest<br>1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| | % | | | | | | | |
| GK 600 | 94 a A† | 87 a B | 81 b B | 82 a B | 80 a B | 73 a C | 65 b C | - |
| Millex 32 | 74 b A | 74 b A | 75 b A | 72 b AB | 66 b BC | 60 b C | 49 c D | |
| Tifleaf 2 | 98 a A | 93 a AB | 89 a B | 87 a B | 86 a B | 79 a C | 79 a C | - |
| Hygrazer | 68 b B | 77 b A | 77 b A | 80 a A | 80 a A | 80 a A | 63 b B | - |
| SX 15 | 69 b BC | 79 b A | 77 b AB | 83 a A | 80 a A | 74 a B | 61 b C | 32 D |
| SE | 2.5 | 2.4 | 2.4 | 2.4 | 2.4 | 2.8 | 4.1 | 6.3 |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. There was a genotype by harvest interaction for leaf percentage in 1997 ($P < 0.0001$).

pearl millets in 1996, however, in 1997, Millex 32 had a lower leaf percentage than the other millets, and also had a lower leaf percentage than the sorghums after the third harvest (Tables 3.11 and 3.12). Interaction occurred in 1996 because two pearl millet genotypes (Millex and Tifleaf 2) had a smaller decline in leaf percentage from first to last harvest (6-14 units) than did the other three genotypes (22-26 units, Table 3.11). In 1997, interaction occurred because the sorghums genotypes increased leaf percentage from first to second harvest (Table 3.12).

## Nutritive Value

### Total herbage crude protein

There were no genotype by planting date interactions for total herbage CP ($P >$ 0.68) in either year (Table 3.1). The earliest planting dates had the lowest CP concentration in both years (Table 3.13). Two reasons may explain this response in part. Earlier planting dates had a greater number of harvests (7-8 relative to 4-5) and the N fertilization protocol provided that N applications occur only after the first four harvests. Thus, earlier dates had more harvests that were not preceded by N application and higher yields resulting in greater dilution of N. Additionally some N applications for the late planting date treatments occurred after the heaviest summer rains had concluded, rains that may have leached some N from soil under earlier planting dates. Therefore, more N fertilizer per harvest and perhaps less leaching of fertilizer N characterized later planting dates. In Jordan, Hattab and Harb (1991) and Harb and Hattab (1991) found no effect of sorghum-sudangrass planting date on herbage CP, and the range of CP in their studies was 124 to 80 $\text{g kg}^{-1}$ DM for the first to fifth harvest.

Table 3.13. Genotype and planting date effects on crude protein and in vitro organic matter digestion (IVOMD) of total herbage of pearl millet and sorghum-sudangrass genotypes planted at four planting dates in 1996 and six planting dates in 1997

| | Crude protein | | IVOMD | |
|---|---|---|---|---|
| Planting date | 1996 | 1997 | 1996 | 1997 |
| | ——— g kg$^{-1}$ DM ——— | | ——— g kg$^{-1}$ OM ——— | |
| Late-March | - | 127 c | - | 660 a |
| Early-April | - | 145 b | - | 666 a |
| Early-May | 133 b† | 130 c | 695 a | 663 a |
| Late-May | 131 b | 153 a | 678 b | 667 a |
| Early-June | 165 a | 143 b | 694 a | 664 a |
| Early-July | 178 a | 143 b | 662 c | 674 a |
| SE | 7.2 | 2.6 | 4.9 | 4.4 |
| Genotype | | | | |
| GK 600 | 160 a | 144 a | 683 a | 660 a |
| Millex 32 | 157 a | 141 a | 681 a | 662 a |
| Tifleaf 2 | 158 a | 143 a | 685 a | 665 a |
| Hygrazer | 150 a | 142 a | 688 a | 668 a |
| SX 15 | 134 a | 132 b | 695 a | 673 a |
| SE | 8.6 | 2.7 | 5.9 | 4.5 |

† Values within a column followed by the same letter are not different ($P > 0.05$) by LSD.
There was no genotype by planting date interaction for crude protein or IVOMD in 1996 or in 1997 ($P > 0.57$).

There were no differences among genotypes for total herbage CP concentration in 1996 ($P = 0.1741$), but there were in 1997 ($P = 0.0441$, Table 3.1). In 1997, SX 15 sorghum-sudangrass had the lowest CP concentration (Table 3.13).

Total herbage CP concentration was affected by genotype by harvest interactions in both years ($P = 0.0001$, Table 3.1). Of all harvests in the 2 yr, there were differences among genotypes only in the first and second harvests of 1997 (data not presented). During the first harvest of 1997, Tifleaf 2 pearl millet had the highest CP concentration (151 g $kg^{-1}$), but in the second harvest Tifleaf 2 was the lowest. Harvest number effects on CP are shown (Fig. 3.5) across genotypes because the interaction of genotype and harvest number was generally due to changes in magnitude as opposed to direction of response. Harvest number changes in CP reflected rainfall conditions in the 2 yr. During 1996, herbage CP increased during the later part of the year when rainfall was less, but in the drier year of 1997, CP declined as the season progressed.

Total herbage IVOMD

There was no genotype by planting date interaction for IVOMD in either year (Table 3.1), and also there were no differences among genotypes in IVOMD (Table 3.13). There was a planting date effect in 1996 ($P < 0.0002$), but not in 1997 ($P > 0.41$). In 1996, the July planting date had the lowest IVOMD (662 g $kg^{-1}$ OM), while the early May and early June dates had highest IVOMD (694-695 $kg^{-1}$, Table 3.13). The absence of large differences either year suggest that harvests were done at about the same growth stage. Hattab and Harb (1991) and Harb and Hattab (1991) found no effect of planting date for IVDMD of sorghum-sudangrass, but they noted a reduction in IVOMD from 540

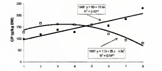

Figure 3.5 Effect of harvest on total herbage mass CP of five pearl millet and sorghum-sudangrass genotypes in 1996 and 1997 Data are LSmeans across five genotypes, four (1996) or six (1997) planting dates, and four replicates. **P < 0.01

to 443 g kg$^{-1}$ DM as well as an increase in crude fiber from 328 to 377 g kg$^{-1}$ DM from the first to fifth harvests

There was a genotype by harvest interaction for total herbage IVOMD in both years (P < 0.0001, Table 3.1) Similar to the interaction for CP, harvest number effects on IVOMD of the genotypes were of similar direction but sometimes of different magnitude. Because direction of the response was similar, data are plotted across genotypes (Fig 3.6) There were differences in IVOMD of total herbage during the first three harvests in both years During these periods there were no differences between sorghum-sudangrass genotypes, however SX 15 had greater IVOMD than at least one pearl millet genotype in each of three first harvests in both years The harvest number effects on IVOMD across genotypes was similar to that for CP (Figs 3.5 and 3.6). In 1996, IVOMD increased from

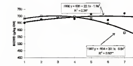

Figure 3 6. Effect of harvest on total herbage mass IVOMD of five pearl millet and sorghum-sudangrass genotypes in 1996 and 1997 Data are LSmeans across five genotypes, four (1996) or six (1997) planting dates, and four replicates
$^{*}P < 0.05$ $^{**}P < 0.01$

about 650 g kg$^{-1}$ at harvest 1 to 690 g kg$^{-1}$ at harvest 8, but in 1997 IVOMD increased approximately 20 units from harvest 1 to harvest 2 (680 to 700 g kg$^{-1}$), leveled off and the decreased to 560 to 600 g kg$^{-1}$ in the last harvest (Fig. 3 6) Cansley (1989) found similar IVOMD (650-670 g kg$^{-1}$ DM) for Sudax sorghum-sudangrass pasture during summer to early fall. McCartor and Rouquette (1977) reported IVDMD from 363 to 636 g kg$^{-1}$ DM for Millex 23 pearl millet when it was grazed at different grazing pressures and IVOMD was inversely related to length of trial.

### Leaf and culm crude protein

There was no genotype by planting date interaction ($P > 0.50$) for CP of leaf or culm in 1996 or 1997, however, there were differences ($P < 0\ 05$) among planting dates in both years (Table 3 1). Leaf and culm CP concentrations increased from May to July planting dates in 1996 (Table 3 14) In 1997, the last three planting dates had greater leaf CP concentration than March and early May plantings (170 vs 150 g kg$^{-1}$ DM) Differences for culm CP in 1997 were limited to the early May planting date that was lowest in CP concentration (75 g kg$^{-1}$ DM) and the early April planting that was higher than all but the March and late May plantings (Table 3 14)

There were no differences among genotypes for leaf CP concentration in 1996 ($P > 0\ 187$) and 1997 ($P > 0\ 055$) and leaf CP averaged about 165 (1996) and 164 (1997) g kg$^{-1}$ DM (Tables 3 1 and 3 14) There were no differences among genotypes for culm CP concentration in 1996 ($P > 0\ 32$), but there were differences in 1997 ($P < 0\ 0077$) In 1997, the pearl millet genotypes presented higher culm CP concentration than both sorghum-sudangrass genotypes (Table 3 14), confirming a trend that existed in 1996 There was genotype by harvest interaction for leaf and culm CP concentration in both years ($P < 0\ 04$) There were differences among genotypes for leaf CP concentration in only one harvest in 2 yr and for culm CP concentration in only two harvests Leaf and culm CP followed the same seasonal trends as described for total herbage in both years (Figs. 3 7 and 3 8)

### Leaf and culm IVOMD

There were no genotype by planting date interactions ($P > 0.23$) for IVOMD of leaf and culm components in 1996 and 1997 (Table 3 1), but there were planting date

Table 3 14 Genotype and planting date effects on crude protein of leaf and culm fractions of pearl millet and sorghum-sudangrass genotypes planted at four dates in 1996 and six dates in 1997

| | Leaf CP | | Culm CP | |
|---|---|---|---|---|
| Planting date | 1996 | 1997 | 1996 | 1997 |
| | g kg$^{-1}$ DM | | | |
| Late-March | - | 150 b | - | 102 ab |
| Early-April | - | 170 a | - | 111 a |
| Early-May | 144 c† | 147 b | 92 b† | 75 c |
| Late-May | 144 c | 177 a | 100 b | 98 ab |
| Early-June | 174 b | 170 a | 130 b | 91 b |
| Early-July | 199 a | 170 a | 148 a | 95 b |
| SE | 7.6 | 3.6 | 14.6 | 5.0 |
| Genotype | | | | |
| GK 600 | 173 a | 163 ab | 127 a | 103 a |
| Millex 32 | 176 a | 170 a | 137 a | 102 a |
| Tifleaf 2 | 167 a | 160 ab | 125 a | 101 a |
| Hygrazer | 162 a | 168 a | 107 a | 88 b |
| SX 15 | 147 a | 159 b | 91 a | 84 b |
| SE | 9.1 | 3.6 | 16.8 | 4.8 |

† Values within a column followed by the same letter are not different ($P > 0.05$) by LSD There was no genotype by planting date interaction for leaf or culm CP in either year ($P > 0.50$)

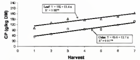

Figure 3.7. Effect of harvest on leaf and culm CP of five pearl millet and sorghum-sudangrass genotypes in 1996. Data are LSmeans across four planting dates and four replicates. $^{**}P < 0.01$

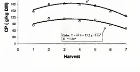

Figure 3.8. Effect of harvest on leaf and culm CP of five pearl millet and sorghum-sudangrass genotypes in 1997. Data are LSmeans across six planting dates and four replicates. $^{*}P < 0.05$ $^{**}P < 0.01$

effects on leaf and culm in 1996 and leaf in 1997 ($P < 0.05$). In 1996, the early June planting had the greatest leaf and culm IVOMD (Table 3.15). In 1997, May plantings had lower leaf IVOMD than April or July plantings, but there were no planting date effects for culm IVOMD (Table 3.15). Although planting date differences were observed for leaf IVOMD, in general IVOMD was quite high and occurred in a relatively narrow range of 680 to 710 g kg$^{-1}$ for leaf and from 630 to 690 g kg$^{-1}$ for culm.

There were genotype differences for leaf IVOMD in both years ($P < 0.001$) and for culm IVOMD in 1997 (Table 3.1). SX 15 sorghum-sudangrass had the greatest leaf IVOMD in both years (Table 3.15). There were no differences among genotypes for culm IVOMD in 1996 ($P = 0.44$), but in 1997 SX 15 was superior, but did not differ from Hygrazer sorghum-sudangrass (Table 3.15). House et al. (1995) characterized pearl millet culm as more woody than sorghum culm at maturity.

There was a genotype by harvest interaction ($P = 0.0001$) for leaf IVOMD in both years, and for culm IVOMD ($P = 0.0273$) in 1997 (Table 3.1). SX 15 sorghum-sudangrass presented greater leaf IVOMD than the pearl millets in the first and second harvests in both years, but after the second harvest of 1996 it presented similar leaf IVOMD to at least one pearl millet genotype. There were no differences among genotypes for culm IVOMD on first, fifth, sixth, and seventh harvests in 1997, however SX 15 sorghum-sudangrass presented greater culm IVOMD than GK 600 pearl millet in the second harvest, and greater than all pearl millet genotypes in the third and fourth harvests of 1997. The harvest number effect on leaf and culm IVOMD was similar to that already described for total herbage (Figs. 3.9 and 3.10).

Table 3.15 Genotype and planting date effects on in vitro organic matter digestion of leaf and culm components of pearl millet and sorghum-sudangrass genotypes planted at four planting dates in 1996 and six planting dates in 1997

| | Leaf IVOMD | | Culm IVOMD | |
|---|---|---|---|---|
| Planting date | 1996 | 1997 | 1996 | 1997 |
| | $g\ kg^{-1}$ OM | | | |
| Late-March | - | 683 ab | - | 661 a |
| Early-April | - | 691 a | - | 667 a |
| Early-May | 688 b† | 678 b | 631 b | 654 a |
| Late-May | 678 b | 676 b | 638 b | 665 a |
| Early-June | 710 a | 689 ab | 688 a | 658 a |
| Early July | 687 b | 695 a | 628 b | 658 a |
| SE | 5.0 | 4.5 | 12.4 | 7.4 |
| Genotype | | | | |
| GK 600 | 684 bc | 679 bc | 638 a | 640 c |
| Millex 32 | 678 c | 687 b | 631 a | 651 bc |
| Tifleaf 2 | 684 bc | 675 c | 640 a | 657 bc |
| Hygrazer | 695 b | 684 bc | 662 a | 666 ab |
| SX 15 | 712 a | 702 a | 660 a | 690 a |
| SE | 6.0 | 4.3 | 14.8 | 6.8 |

† Values within a column followed by the same letter are not different ($P > 0.05$) by LSD. There was no genotype by planting interaction ($P > 0.23$) for leaf or culm in either year.

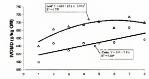

Figure 3.9 Effect of harvest on leaf and culm IVOMD of five pearl millet and sorghum-sudangrass genotypes in 1996. Data are LSmeans across four planting date and four replicates. *P < 0.05

## Summary and Conclusions

A 2-yr experiment was conducted at the Beef Research Unit, University of Florida, northeast of Gainesville to compare yield, seasonal yield distribution, and nutritive value of pearl millet and sorghum-sudangrass genotypes planted at different dates and harvested frequently. Total herbage yield decreased linearly as planting date was delayed. Between sorghums, SX 15 had greater total DM yield than Hygrazer for late plantings (late May to early July). Yield differences among cultivars was not consistent from year to year. Although the greatest herbage yield occurred in summer, forage distribution may be

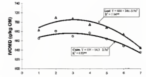

Figure 3.10. Effect of harvest on leaf and culm IVOMD of five pearl millet and sorghum-sudangrass genotypes in 1997. Data are LSmeans across six planting dates and four replicates. **P < 0.01

improved and the autumn forage deficit reduced by planting pearl millet and or sorghum-sudangrass genotypes at two or more dates and utilizing management including frequent harvests. Leaf percentage for most cultivars decreased linearly as planting date was delayed. Tifleaf 2 millet had or tended to have the greatest leaf percentage independent of planting or harvest date, and decreased from earlier plantings to June and from June to July plantings. Nutritive value was high, and CP concentration across planting dates and genotypes ranged from 144 to 199, 75 to 148, and 127 to 178 g kg$^{-1}$ DM, respectively, for leaf, culm, and total herbage, while IVOMD ranged between 675 to 712, 628 to 690, and 660 to 695 g kg$^{-1}$ OM for the same fractions. Total herbage and leaf had the lowest CP concentrations in the earliest planting date. Among genotypes there were no differences in IVOMD and CP concentration for total herbage, except for 1 yr when SX 15 had the lowest CP concentration for total herbage, leaf, and culm. It also had the highest leaf IVOMD in both years, and highest culm IVOMD in 1 yr.

These data suggest that warm-season annual grasses provided high nutritive value forage for grazing by lactating dairy cows when harvested frequently. Multiple planting dates improved forage distribution and extended the grazing season about 30 d, during a time of the year when warm-season perennial grasses usually have low nutritive value

# CHAPTER 4
# EFFECT OF PLANTING DATE ON FORAGE YIELD AND NUTRITIVE VALUE OF ANNUAL COOL-SEASON MIXTURES

## Introduction

Confinement housing and feeding byproduct fiber sources or conserved forage as components of total mixed rations characterize the Florida dairy industry, however, in the last 5 yr some producers have adopted pasture-based feeding systems that rely on grazing of perennial warm-season grasses These forages do not supply adequate quantity or quality during late fall through spring. Cool-season annual grasses and legumes have potential to fill some of this gap

Cool-season forages are high in quality and may provide valuable fall through spring grazing. Mixtures of these species are used to increase forage production, to lengthen the forage production season, and to reduce the risk of not having forage for grazing (Phillips et al., 1996) Mixtures of ryegrass (*Lolium multiflorum* Lam.) with small grains have been used for dairy cows and for younger animals that require high nutritive value The addition of a small grain allows for earlier grazing compared to ryegrass alone. Clovers (*Trifolium spp* ) grown in mixtures with grasses can increase herbage crude protein (CP), reduce N fertilizer input, increase forage intake, and increase animal performance due to their superior feed value to that of grasses (Pedersen and Ball, 1991) Legumes added to a rye (*Secale cereale* L.)-ryegrass mixture were found to supply N, maintain nutritive value, and extend the grazing season in late spring (Hoveland and Alison, 1982). In addition, N fertilizer economy due to presence of legumes in the pasture may increase environmental sustainability.

Early this century, Ferris (1917) reported that oat (*Avena sativa* L.)-legume pasture and ryegrass-clover provided excellent nutritive value forage for grazing dairy cows in the winter months in Mississippi. Bagley et al. (1988) reported daily gains of steers above 0.90 kg in pastures of ryegrass-ladino clover (*Trifolium repens* L.). In a 3-yr trial, Hoveland et al. (1991) reported daily gains of steers of 1.18 kg on rye-ryegrass-crimson clover (*Trifolium incarnatum* L.) pastures. Rye and clover were beneficial for enhancing forage availability and animal gains, respectively. Dairy cow performance on cool-season pastures has been reported to range from 15 to 17 kg of fat corrected milk per cow daily and from 5000 to 12000 kg $ha^{-1}$ $yr^{-1}$ (Burns and Bagley, 1996). Marshall (1957) in Florida, reported milk production of 14.7 kg $d^{-1}$ for cows grazing oat pasture, and heifers receiving no supplemental feed gained an average of 0.5 kg $d^{-1}$ and a total of 264 kg $ha^{-1}$. In New Zealand, Thom and Bryant (1996 a,b) reported milk production of 3600 to 3800 kg $cow^{-1}$ when grazing 'Concord' annual ryegrass during a 270-d lactation.

Soil moisture (rainfall) is the key to successfully growing cool-season forages in Florida (Stanley, 1999b). The optimum planting date of cool-season annual grasses to be used for forage should be 3 to 4 wk before the optimum planting date for grain in that region, but at that time there is increased susceptibility to insects and diseases (Phillips et al., 1996). Planting pastures at different planting dates may reduce risks of establishment failure due to undesirable environmental conditions at one date and may improve distribution of dry matter (DM) and nutritive value. Choice of species or combinations of species may also have a major impact on pasture productivity and distribution of quantity and quality Information is needed regarding the effects of species combinations and planting dates on seasonal distribution of yield and quality of these forages

The present study was conducted in north central Florida during the cool-seasons of 1996-1997 and 1997-1998. The objective was to determine the effect of planting date on forage yield, forage distribution, and nutritive value of six cool-season forage mixtures

## Materials and Methods

The experiment was conducted at the Beef Research Unit of the University of Florida, north of Gainesville, Florida during cool seasons of 1996-97 (referred to as the 1996 year) and 1997-98 (referred to as the 1997 year) Soils belonged to the Plummer Series (loamy, siliceous, thermic Grossarenic Paleaquults) in 1996, and to the Sparr Series (loamy, siliceous, hyperthermic Grossarenic Paleudults, USDA, 1985) in 1997. Mean soil pH was 6 8 and Mehlich 1 extractable P and K were 26 and 30 mg kg$^{-1}$, respectively

Four planting dates at 4-wk intervals were tested from September to December each year (19 Sept. 17 Oct., 14 Nov , and 11 Dec 1996 and 2 Oct , 30 Oct., 25 Nov , and 23 Dec 1997) The mixture treatments were rye-oat (R-O), rye-oat-ryegrass (R-O-Rg), rye-oat-crimson clover (R-O-Crim) rye-oat-ryegrass-crimson clover (R-O-Rg-Crim), rye-oat-red clover (R-O-Red), and rye-oat-ryegrass-red clover (R-O-Rg-Red) Cultivars used were 'Surrey' ryegrass, 'Ozark' oat, 'Grazemaster' rye, Dixie' crimson clover, and 'Cherokee' red clover (*Trifolium pratense* L )

Plot size was 21 $m^2$ Treatments were arranged as a split-plot experiment in four replicates of a randomized complete block design with planting date as the main plot and forage mixture as the subplot. Seeding rates were 64, 36, 16, 17, and 8.5 kg $ha^{-1}$ for rye, oat, ryegrass, crimson, and red clover, respectively The appropriate *Rhizobium trifolii* inoculant was applied to clover seed immediately prior to planting. The small grains and ryegrass were seeded into a prepared seedbed using a drill in a 15-cm row spacing at a 3 to 5 cm seeding depth. The clovers were broadcast by hand, after which one pass was made with a cultipacker seeder

The P (18 kg $ha^{-1}$) and K (66 $kg^{-1}$) were applied according to soil test recommendations 10 to 14 d after planting each year. Fourty kg of N $ha^{-1}$ was applied together with P and K. The same amount of N was applied after each of the first two harvests of the mixtures with clover, and after each of the first three harvests of the mixtures without clover, resulting in totals of 120 kg N $ha^{-1}$ and 160 kg N $ha^{-1}$, respectively Because of slower than normal growth and very high rainfall, the second N application for the 1997 planting was made on 22 Jan. 1998, before the first harvest however, the total seasonal amount was the same as in the first season.

Plots were sampled when forage was 25 to 40 cm tall using a sickle-bar mower to cut to a 7- to 10-cm stubble height. The number of harvests was six, six, five, and four for the 19 Sept , 17 Oct , 14 Nov , and 11 Dec 1996 planting dates, respectively Number of harvests was three for the 2 Oct. 30 Oct., and 25 Nov 1997 planting dates, and two for the 23 Dec 1997 planting. After removing borders, an area of 10 $m^2$ was clipped, weighed, and two sub-samples were taken. One was used for determination of DM and the other for botanical composition. Samples were separated by hand into small grains (rye-oat), ryegrass, clovers, and other (including weed species and senescent and dead material). Total herbage samples and each forage component of the pasture were ground to pass a 1-mm screen using a Wiley mill and analyzed for in vitro organic matter digestibility (IVOMD) and CP. Samples were digested for N determinations using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Ammonia in the digestate was determined by semiautomatic colorimetry (Hambleton, 1977). The CP (DM basis) was calculated as N x 6.25. The IVOMD concentration was determined using the two-stage procedure of Tilley and Terry (1963) as modified by Moore and Mott (1974). Laboratory analyses were conducted in the Forage Evaluation Support Laboratory (FESL), located on the campus of the University of Florida.

Growth period and total-season forage production were calculated by summing across harvests. The harvests were grouped into five growth periods based on solstice and equinox dates. The growth periods were named late fall (8 November to 21 December), early winter (22 December to 5 February), late winter (6 February to 20 March), early spring (21 March to 8 May), and late spring (9 May to 21 June). Total annual production was also summed.

Data were analyzed using the Statistical Analysis System software package (SAS, 1989). Across growth periods, data were analyzed as repeated measures using PROC MIXED model for repeated measures (Littell et al., 1996, Littell et al., 1998, SAS, 1989). To determine the effects of year, planting date, and mixture in total DM production, data were analyzed as a split-split-plot experiment (Montgomery, 1991) also using a PROC MIXED model (year as main plot, date as sub-plot and mixture as sub-sub-plot). To determine the effects of planting date and mixtures on botanical composition (rye-oat, ryegrass, and clovers) data were analyzed using the General Linear Models procedures (PROC GLM). Differences among treatments were considered to be significant at $P < 0.05$. Means were separated using the least significant difference (LSD) method (SAS Institute, 1989).

## Results and Discussion

### Forage Yield and Botanical Composition

#### Total forage yield

There were year by mixture ($P < 0.024$, Table 4.1) and planting date by mixture ($P < 0.0001$) interaction effects on total DM yield (Table 4.2), but there was no planting date by year interaction ($P > 0.24$, Table 4.2). The R-O-Rg mixture had greatest total DM yield for both years, but was not different than R-O-Crim in 1996 (Table 4.1). The forage production in 1996 was 45% greater than in 1997. The decrease in yield in the second year was less for mixtures with, than those without, ryegrass. In the second season, ryegrass mixtures produced 75% as much forage as produced in the first season, whereas mixtures without ryegrass produced just 65% as much forage as in the first year (Table 4.1). Rainfall was an important determinant of performance. In the first year, there was a dry period during February and March 1997, when rainfall was just 40% of normal, i.e., 110 mm lower than normal. During the period from October 1997 to February 1998, rainfall was 550 mm above normal (Table 4.3). During February 1998 alone, there was 323 mm of rainfall, a Gainesville record, and 240 mm above the 70-yr normal of 83 mm.

Table 4.1. Year by mixture interaction for total dry matter yield of six cool-season forage mixtures planted at four planting dates in 1996 and 1997.

| Mixture† | 1996 | 1997 | SE |
|---|---|---|---|
| | kg DM ha$^{-1}$ | | |
| R-O† | 3670 b A‡ | 2470 b B | 290 |
| R-O-Rg | 4360 a A | 3170 a B | 287 |
| R-O-Crim | 4050 a A | 2380 b B | 287 |
| R-O-Rg-Crim | 3500 b A | 2660 b B | 287 |
| R-O-Red | 3620 b A | 2400 b B | 287 |
| R-O-Rg-Red | 3380 b A | 2460 b B | 287 |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover
‡ Values within a column followed by the same lower case letter and in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD

Excessive rain appeared to leach N fertilizer and reduce yields, especially those of small grains. March 1998 rainfall was normal, but was followed by an April through May drought, with 150 mm lower than normal rainfall. This also contributed to lower second-year yields.

The two intermediate planting dates generally resulted in greatest DM yield (Table 4.2), and the R-O-Rg mixture had the greatest total DM yield for those dates. The R-O mixture had the greatest total DM yield for first planting date, but R-O yielded lower than R-O-Rg and R-O-Crim in the December plantings (Table 4.2). There was no effect of planting date on total DM yield for R-O-Crim and R-O-Red; however, ryegrass mixtures

Table 4 2 Planting date by mixture interaction for total dry matter yield of six cool-season mixtures planted at four planting dates in 1996 and 1997

| Mixture | Planting date<br>19 Sept 1996<br>2 Oct 1997 | <br>17 Oct 1996<br>30 Oct 1997 | <br>14 Nov 1996<br>25 Nov 1997 | <br>11 Dec 1996<br>23 Dec. 1997 | SE |
|---|---|---|---|---|---|
| | | | kg DM $ha^{-1}$ | | |
| R-O† | 3410 a A‡ | 3310 b A | 3140 b A | 2400 c B | 343 |
| R-O-Rg | 2760 bc C | 4240 a A | 4500 a A | 3560 a B | 343 |
| R-O-Crm | 2910 b A | 3270 b A | 3510 b A | 3150 ab A | 343 |
| R-O-Rg Crm | 2640 bc C | 3270 b AB | 3620 b A | 2810 bc BC | 343 |
| R-O-Red | 2790 bc A | 3280 b A | 3210 b A | 2760 bc A | 343 |
| R-O-Rg-Red | 2410 c B | 3240 b A | 3530 b A | 2500 c B | 343 |

† R = rye, O = oat, Rg =ryegrass, Crm = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD

Table 4.3 Monthly rainfall at Beef Research Unit of University of Florida in 1996-98.

| Month | 1996 | 1997 | 1998 | Normal† |
|---|---|---|---|---|
| | mm | | | |
| January | | 68 | 99 | 66 |
| February | | 29 | 323 | 83 |
| March | | 48 | 96 | 104 |
| April | | 211 | 4 | 94 |
| May | 155 | 64 | 33 | 88 |
| June | 192 | 144 | 91 | 169 |
| July | 318 | 144 | 148 | 190 |
| August | 112 | 52 | 168 | 195 |
| September | 62 | 73 | 307 | 126 |
| October | 130 | 112 | 5 | 107 |
| November | 23 | 136 | 6 | 44 |
| December | 104 | 242 | 19 | 64 |
| Total | 1096 | 1323 | 1299 | 1332 |

† Normal is that reported for the Univ. of Florida Agronomy Farm in Gainesville, FL.

increased DM yield from 19 Sept. 1996 and 2 Oct. 1997 to late October plantings, whereas R-O and ryegrass mixtures decreased yield from November to December plantings (Table 4.2). Elder (1960) studied clipping responses of small grains to six plantings dates from September to November and reported a reduction in total DM yield due to delayed plantings.

Botanical Composition and Component Yields

Rye-oat was the most important component for all mixtures in 1996, averaging about 50 and 70% of total DM for mixtures with and without ryegrass, respectively (Tables 4.4 and 4.5, Figs. 4.1 and 4.2). Small grain contributed from 78 to 98% of total DM for the R-O mixture, and weeds and dead material contributed from 2 to 22% (Figs. 4.1 and 4.2). In small grain-clover mixtures, the small grain component was about 60% of total DM yield, and it was about 38% for mixtures of small grain-ryegrass-clover (Table 4.4, Figs. 4.1 and 4.2). There were differences in percentage of rye-oat in total DM between R-O-Crim and R-O-Red for only the October 1997 plantings. Similarly small grain-ryegrass-clover mixtures had differences in percentage of rye-oat only for the 30 Oct. and 23 Dec. 1997 plantings (Table 4.4). There were no differences among clover mixtures for rye-oat DM yield for September and October 1996 and 2 Oct. 1997 plantings. However for plantings from November through December, rye-oat DM yield of clover mixtures without ryegrass was greater than in clover-ryegrass mixtures in both years (Table 4.5).

Table 4 4 Planting date by mixture interaction for percentage of rye-oat in total DM of six cool-season forage mixtures planted at four planting dates in 1996 and 1997

| Mixture | Planting date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 19 Sept | 2 Oct | 17Oct | 30 Oct. | 14 Nov | 25 Nov | 11 Dec. | 23 Dec |
| | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 | 1996 | 1997 |
| | % | | | | | | | |
| R-O† | 78 a‡ | 94 a | 82 a | 98 a | 93 a | 96 a | 98 a | 88 a |
| R-O-Rg | 41 c | 31 c | 42 c | 31 c | 57 b | 22 b | 50 c | 9 de |
| R-O-Crim | 52 b | 72 b | 54 b | 87 a | 60 b | 78 a | 65 b | 42 b |
| R-O-Rg-Crim | 41 c | 33 c | 46 c | 69 b | 48 b | 19 b | 53 c | 21 cd |
| R-O-Red | 55 b | 49 c | 66 b | 52 b | 69 ab | 54 a | 66 b | 42 b |
| R-O-Rg-Red | 45 c | 33 c | 51 bc | 26 c | 53 b | 16 b | 52 c | 3 e |
| SE | 1996 – 3.8 | | 1997 = 6.6 | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction in 1996 and in 1997 ($P < 0.0001$)

Table 4.5. Planting date by mixture interaction for rye-oat DM yield of six cool-season forage mixtures planted at four planting dates in 1996 and 1997

| | Planting date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mixture | 19 Sept | 2 Oct | 17Oct. | 30 Oct | 14 Nov | 25 Nov | 11 Dec | 23 Dec. |
| | 1996 / 1997 | | 1996 / 1997 | | 1996 / 1997 | | 1996 / 1997 | |
| | kg DM ha$^{-1}$ | | | | | | | |
| R-O† | 2470 a‡ | 2160 a | 4330 a | 2470 a | 3670 a | 2270 a | 2990 a | 1130 a |
| R-O-Rg | 820 b | 870 b | 2660 b | 760 cd | 2010 c | 860 c | 2040 bc | 200 b |
| R-O-Crim | 920 b | 1290 b | 2370 b | 1760 b | 2540 b | 1840 ab | 2460 b | 1060 ab |
| R-O-Rg-Crim | 610 b | 740 b | 2300 b | 1370 bc | 1800 c | 480 c | 1700 c | 520 bc |
| R-O-Red | 930 b | 1160 b | 2760 b | 1290 bc | 2530 b | 1390 b | 2500 ab | 1480 a |
| R-O-Rg-Red | 730 b | 730 b | 2350 b | 530 d | 1880 c | 440 c | 1680 c | 50 c |
| SE | 1996 = 78 | | 1997 = 131 | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction in 1996 ($P < 0.0447$) and in 1997 ($P < 0.0548$)

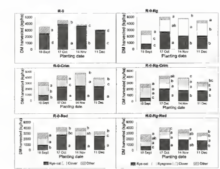

Figure 4.1 Contribution to total DM yield of components of cool-season forage mixtures planted at four planting dates in 1996. Date effects for a given botanical component were separated using Fisher's LSD test. Within a mixture type and botanical component, bars followed by the same letter are not different (P>0.05). R=rye, O=oat, Rg=ryegrass, Crim=crimson clover, and Red=red clover.

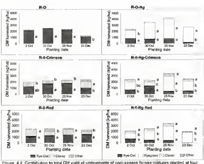

Figure 4.2 Contribution to total DM yield of components of cool-season forage mixtures planted at four planting dates in 1997. Date effects for a given forage botanical component were separated using Fisher's LSD test. Within a mixture type and botanical component, bars followed by the same letter are not different (P>0.05). R=rye, O=oat, Rg=ryegrass, Crim=crimson clover, and Red=red clover.

There was no planting date effect on percentage ryegrass in 1996 Ryegrass averaged 41% for the R-O-Rg mixture and about 20% for R-O-Rg-clover mixtures (Table 4 6 and Fig. 4 1) In the wet year of 1997, ryegrass contribution rose to above 60% for the R-O-Rg mixture and above 70% for the November and December planting dates (Table 4 6) with yields of 2500 kg DM ha$^{1}$ or more (Table 4 7 and Fig 4.2) These data support the conclusions of other authors that annual ryegrass is more tolerant to excessive soil moisture than small grains (Ball et al., 1991, Phillips et al., 1996, Stanley, 1999b)

The clover component was quantitatively important, contributing 12 to 45% of total DM in the mixtures without ryegrass, and 6 to 29% in ryegrass mixtures (Table 4 8) As observed for small grains and ryegrass, there were year differences in clover percentage in the mixtures. Crimson clover contributed a greater proportion of DM yield in the drier year of 1996, while red clover percentage was higher in the wet year of 1997 The average percentage of crimson clover decreased from about 26 to 17%, whereas red clover increased from about 15 to 25% in 1996 and 1997, respectively (Table 4 8) This was true in mixtures with or without ryegrass, thus it seems likely that the effect was weather related instead of being only due to degree of competition from other forages in the mixture Crimson clover yield decreased from about 1200 in 1996 to 450 kg DM ha$^{1}$ in 1997, while red clover maintained yield of about 600 kg DM ha$^{1}$ (Table 4 9) Clover had or tended to have greater DM yield in mixtures without ryegrass than with (Table 4 9)

Addition of ryegrass to the R-O mixture reduced rye-oat yield by approximately half Clovers also reduced rye-oat yield, when comparing the R-O mixture with R-O-Crim and R-O-Red, but they generally were not as competitive with R-O as was ryegrass

Table 4.6 Mixture effects on percentage ryegrass in 1996 and planting date by mixture interaction for percentage ryegrass in 1997

| Mixture | | Planting date | | | |
|---|---|---|---|---|---|
| | | 2 Oct | 30 Oct. | 25 Nov | 23 Dec |
| | 1996 | 1997 | 1997 | 1997 | 1997 |
| | | | % | | |
| R-O-Rg† | 41 a‡ | 62 a | 67 a | 74 b | 91 a |
| R-O-Rg Crim | 21 b | 54 ab | 19 b | 88 a | 60 b |
| R-O-Rg-Red | 18 b | 40 b | 61 a | 58 c | 87 a |
| SE | 1996 = 4.5 | 1997 = 7.6 | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction in 1996 ($P < 0.2077$) and in 1997 ($P < 0.0001$)

Table 4.7 Mixture effects on ryegrass DM harvested in 1996 and planting date by mixture interaction for ryegrass DM harvested in cool-season forage mixtures planted at four planting dates in 1997

| Mixture | | Planting date | | | |
|---|---|---|---|---|---|
| | | 2 Oct | 30 Oct | 25 Nov | 23 Dec. |
| | 1996 | 1997 | 1997 | 1997 | 1997 |
| | kg DM ha$^{-1}$ | | | | |
| R-O-Rg† | 1990 a‡ | 1260 a | 2680 a | 3250 a | 2500 a |
| R-O-Rg-Crim | 720 b | 1240 a | 570 c | 2400 a | 1560 b |
| R-O-Rg-Red | 580 b | 930 a | 1600 b | 2440 a | 1740 b |
| SE | 1996 = 84 | 1997 = 171 | | | |

† R = rye, O = oat, Rg = ryegrass Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction in 1996 ($P < 0.2460$) and in 1997 ($P < 0.0060$)

Table 4.8. Planting date by mixture interaction for percentage of clover in total DM harvested of cool-season forage mixtures planted at four planting dates in 1996 and 1997

| | Planting date | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mixture | 19 Sept | 2 Oct | 17 Oct | 30 Oct | 14 Nov | 25 Nov | 11 Dec | 23 Dec |
| | 1996 / 1997 | | 1996 / 1997 | | 1996 / 1997 | | 1996 / 1997 | |
| | % | | | | | | | |
| R-O-Crim† | 32 a‡ | 24 b | 26 a | 12 b | 36 a | 15 bc | 28 a | 45 a |
| R-O-Rg-Crim | 25 b | 9 c | 20 b | 9 b | 29 b | 10 c | 12 b | 10 b |
| R-O-Red | 21 b | 43 a | 15 b | 32 a | 20 c | 37 a | 14 b | 36 a |
| R-O-Rg-Red | 11 c | 19 b | 19 b | 11 b | 12 d | 17 b | 7 c | 6 b |
| SE | 1996 = 3.5 | | 1997 = 4.4 | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction in 1996 and in 1997 ($P < 0.0001$)

Table 4.9 Mixture effect on clover DM harvested in 1996 and planting date by mixture interaction for clover DM harvested of cool-season forage mixtures planted at four planting dates in 1997.

| Mixture | Planting date | | | | |
|---|---|---|---|---|---|
| | | 2 Oct. | 30 Oct | 25 Nov | 23 Dec |
| | 1996 | 1997 | 1997 | 1997 | 1997 |
| | kg DM $ha^{-1}$ | | | | |
| R-O-Crim† | 1530 a‡ | 590 b | 420 a | 410 b | 1040 a |
| R-O-Rg-Crim | 830 b | 330 b | 220 a | 340 b | 250 b |
| R-O-Red | 780 b | 1130 a | 660 a | 920 a | 390 b |
| R-O-Rg Red | 450 c | 320 b | 280 a | 400 b | 70 b |
| SE | 1996 – 66 | 1997 – 88 | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction in 1996 ($P < 0.1013$) and in 1997 ($P < 0.0116$)

Clovers also reduced ryegrass yield (comparing R-O-Rg with R-O-Rg-Red and R-O-Rg-Crim), but there were no consistent differences between clovers in the degree to which their addition to the mixture reduced yields of either rye-oat (R-O-Crim vs R-O-Red) or ryegrass (R-O-Rg-Crim vs R-O-Rg-Red)

Forage Yield by Growth Period

Treatments with the greatest total yield may not be the best choice if others provide a longer productive period or better distribution of DM. Thus, considering different periods (P) of the growing season, specifically late fall (P1, before 21 December), early winter (P2, 22 December to 5 February), late winter (P3, 6 February to 20 March), early spring (P4, 21 March to 8 May), and late spring (P5, after 8 May), may be useful.

There was no planting date by mixture interaction either in 1996 ($P > 0.15$) or 1997 ($P > 0.95$) for DM yield by growth period. However, there were growth period by mixture and growth period by planting date ($P < 0.0001$) interactions. Consequently, yield responses for growth periods are presented by mixture and planting date

Growth period by mixture interaction effects

Only when planting occurred on 19 Sept 1996 was there a harvest before 21 December (late fall growth period, Fig 4.3) First harvest occurred in late winter for October and November 1997 plantings and only in early spring for December 1997 planting (Fig 4.4) Spring growth periods had greatest yield for many mixtures, but mixtures including clover tended to produce significant forage after 8 May (Tables 4.10 and 4.11). The mixture R-O did not provide any DM for the late spring growth period, by then rye and oat had completed their life cycle Fall and winter forage production from

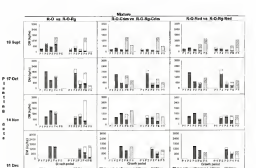

Figure 4.3 Contribution to DM yield by growth period (P) of forage components of cool-season mixtures planted at four planting dates in 1996. R—Rye, O—oat, Rg—ryegrass, Crim—crimson clover, and Red—red clover. P1 = before 21 Dec. (late fall), P2 = 22 Dec. to 5 Feb. (early winter), P3 = 6 Feb. to 20 Mar. (late winter), P4 = 21 Mar. to 8 May (early spring), and P5 = after 8 May (late spring).

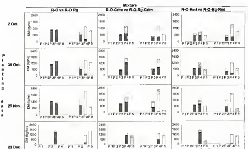

Figure 4.4 Contribution to DM yield by growth period (P) of forage components of cool-season mixtures planted at four planting dates in 1997. R=rye, O=oat, Rg=ryegrass, Crim=crimson clover, and Red=red clover. P1 = before 21 Dec. (late fall), P2 = 22 Dec. to 5 Feb. (early winter), P3 = 6 Feb. to 20 Mar (late winter), P4 = 21 Mar. to 8 May (early spring), and P5 = after 8 May (late spring)

Table 4 10 Growth period by mixture interaction for forage yield in 1996

| Mixture | Growth period | | | | |
|---|---|---|---|---|---|
| | Late-fall† | Early-winter | Late-winter | Early-spring | Late-spring |
| | (8 Nov - 21 Dec ) | (22 Dec -5 Feb) | (6 Feb -20 Mar) | (21Mar -8 May) | (9 May-21 June) |
| | kg DM $ha^{-1}$ | | | | |
| R-O‡ | 90a C§ | 920a B | 1160a B | 1490b A | 0d C |
| R-O-Rg | 100a C | 910a B | 910ab B | 2140a A | 200c C |
| R-O-Crim | 60a C | 690a B | 900ab C | 1860ab A | 1090a B |
| R-O-Rg-Crim | 80a C | 810a B | 730b B | 1600b A | 650b B |
| R-O-Red | 70a C | 750a B | 930ab AB | 750c B | 1120a A |
| R-O-Rg-Red | 100a B | 780a A | 760b A | 850c A | 880ab A |
| SE | 120 | | | | |

† Data are averages across planting dates and only the first planting date plots were harvested in this time period.

‡ R = rye, O = oat, Rg = ryegrass Crim = crimson clover, Red = red clover

§ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD Growth period by mixture interaction ($P < 0.0001$).

Table 4.11  Growth period by mixture interaction for forage yield in 1997

| Mixture | Growth period | | | | |
|---|---|---|---|---|---|
| | Late-fall<br>(8 Nov -21 Dec.) | Early-winter<br>(22 Dec -5 Feb.) | Late-winter<br>(6 Feb -20 Mar.) | Early-spring<br>(21Mar -8 May) | Late-spring<br>(9 May-21 June) |
| | kg DM ha$^{-1}$ | | | | |
| R-O† | - | - | 860a B‡ | 1240b A | 0d C |
| R-O-Rg | - | - | 740ab C | 1520ab A | 1160a B |
| R-O-Crim | - | - | 510b B | 1450ab A | 260cd B |
| R-O-Rg-Crim | - | - | 520ab B | 1620a A | 510bc B |
| R-O-Red | - | - | 530ab B | 1240b A | 540bc B |
| R-O-Rg-Red | - | - | 580ab B | 1430ab A | 720b B |
| SE | 126 | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover.

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Growth period by mixture interaction ($P < 0.0001$)

rye-oat was greater than from ryegrass, whereas later forage from ryegrass was greater than forage production from small grains, agreeing with results of Kee et al. (1995). They tested ryegrass and small grains in three planting dates during September through October and concluded that when planting in early September, including rye or oat with ryegrass allowed earlier grazing in Alabama. The clover mixtures had greatest yield in late spring in 1996, but in 1997 the R-O-Rg mixture had greatest DM yield (Tables 4.10 and 4.11) in that season. To simplify presentation of individual component yields by growth period, data are graphed on Figs. 4.3 and 4.4. Tables showing the numerical data and statistical analyses are in the appendix (Tables A.1 to A.12) and are referenced in the text.

## Rye-oat

Rye-oat DM yield during winter and early spring growth periods (Periods 2, 3 and 4) from the 19 Sept. 1996 planting was lower than that of the October 1996 planting (Fig. 4.3, Tables A.1 to A.3). Early winter (Period 2) was the growth period with greatest DM yield of rye-oat for September and October 1996 plantings, however late winter (Period 3) was the greatest for November and December 1996 plantings (Fig. 4.3 and Tables A.1 to A.3). The contribution of the rye-oat component to total DM yield extended only to early spring.

There was no difference for rye-oat DM yield for October and November 1997 plantings for R-O, R-O-Rg, and R-O-Red mixtures, and during late winter for all mixtures (Fig. 4.4 and Tables A.4 to A.6). The December 1997 planting and rye-oat yield only in early spring (Fig. 4.4). Rye-oat maintained or increased yield from winter to spring for

October and November 1997 plantings, however it decreased yield for the R-O-Rg mixture probably due to ryegrass competition (Fig. 4.4 and Tables A.4 to A.6).

### Ryegrass

Ryegrass had the greatest DM yield during early spring (Figs. 4.3 and 4.4), however for December plantings R-O-Rg had the greatest yield in late spring. Ryegrass and clover mixtures had lower ryegrass DM yield for 1996 plantings, probably due to a dry February and March 1997 period (Tables 4.3, and A.7 and Fig. 4.3). However ryegrass yields during the wet 1997 year were high (Tables 4.3, and A.8, and Fig. 4.4). There were no differences ($P > 0.06$) among mixtures for ryegrass yield during early spring for 2 Oct. and 25 Nov. 1997 plantings, but for the 30 Oct. 1997 planting ryegrass yielded more in the R-O-Rg mixture than in R-O-Rg-Crim. Ryegrass yields were maintained throughout the spring period for October 1997 plantings and reduced for the 25 Nov. 1997 planting (Table A.8).

### Clover

The R-O-Crim treatment had greatest clover yield in early spring for September and October 1996 plantings (Table A.9 and Fig. 4.3) and in late spring for November and December 1996 plantings. For the R-O-Rg-Crim mixture, there was no difference between spring harvests in clover yield for October and November 1996 plantings, whereas for the September planting greatest yield was in early spring winter and for December planting greatest yield was in late spring (Table A.9). During the second year R-O-Crim had the greatest yield in early spring when planted in October and November (Fig. 4.4, Table A.10), but greatest yields were delayed to late spring for December 1997 planting. The R-O-Rg-Crim clover yield was low in 1997, probably because of high rainfall (Table 4.3). Red clover had the greatest yield in late spring and there were no differences in yield for plantings from September to November in either year (Tables A.11 and A.12). The December plantings generally had the lowest red clover yield during late spring in both years. Crimson clover dramatically decreased yield from 1200 kg DM ha$^{-1}$ in 1996 to 450 kg DM ha$^{-1}$ in 1997 plantings, while red clover had about the same yield in both years (600 kg DM ha$^{-1}$).

The main contribution of the ryegrass component was to increase forage production more than to extend the growing season, as illustrated by the R-O-Rg treatment, in 1996 (Fig. 4.3). The clover component was primarily responsible for extending the growing season (Figs. 4.3 and 4.4). The last harvest on mixtures with crimson and red clovers were 18 May and 31 May 1998, respectively. Pederson and Ball (1991), testing several clovers in Alabama, recommended crimson clover as the best choice for early spring production, and red clover and white clover for late-season production. The R-O mixture, i.e., without ryegrass or clovers, permitted harvest not later than early April. The use of ryegrass-clover or ryegrass-N has been reported to provide greater forage production in the spring than winter (Bagley et al., 1988).

Because in small grain-clover mixtures spring forage production is almost exclusively legume, bloat risk is increased. Thus, one of the best combinations appears to be ryegrass-clover-small grain. When growing small-grain species, an important management strategy is to allow accumulation of significant forage mass before the initial grazing (Dalrymple, 1984). When this principle is followed, pastures will have more uniform forage distribution and greater yield than when pastures are grazed too early or too late.

Even when percentage clover is low, it may have a greater impact on animal performance than expected because grazing animals often select legume over grasses (Coleman et al., 1989). In 24 experiments conducted in the USA, steer gains from legume-grass treatments averaged 0.14 kg steer$^{-1}$ d$^{-1}$ more than grass-N treatments, an increase in live weight of 27 to 32 kg animal$^{-1}$ for a 6- to 7-mo grazing season (Burns and Standaert, 1985). Thus, legumes offer potential to improve forage quality and reduce fertilizer costs.

### Growth period by planting date interaction effects

Independent of planting date, early spring production generally was greatest (Tables 4.12 and 4.13, and Figs. 4.3 and 4.4). An exception was the 17 Oct. 1996 planting when early winter production was greatest. Late winter and late spring periods generally were next greatest in DM yield. There was late fall forage production only for the 19 Sept. 1996 planting. In the 1997 season, excessive rainfall delayed the first harvest to late winter for October and November plantings, and to early spring for the last planting (Table 4.13 and Fig. 4.4). Extending the growing season by delaying planting date is demonstrated through December plantings for R-O-Rg and R-O-Rg-Crim (compared to R-O) in 1996 and 1997, respectively (Figs. 4.3 and 4.4). Elder (1960) studied the effect of small grain planting date on forage production and distribution for grazing. A 10 October planting made more growth after early November than did the 10 September planting, but the earlier planting had produced more than twice as much total forage by

Table 4 12. Growth period by planting date interaction for total forage yield in 1996

| Planting date | Growth period<br>Late-fall<br>(8 Nov - 21 Dec ) | <br>Early-winter<br>(22 Dec.-5 Feb ) | <br>Late-winter<br>(6 Feb.-20 Mar ) | <br>Early-spring<br>(21 Mar -8 May) | <br>Late-spring<br>(9 May-21 June) | SE |
|---|---|---|---|---|---|---|
| | kg DM $\text{ha}^{-1}$ | | | | | |
| **19 Sept** | 340 C† | 500 b C | 300 d C | 1480 b A | 1070 a B | 88 |
| **17 Oct.** | - | 1850 a A | 710 c C | 1110 c B | 760 b C | 85 |
| **14 Nov** | - | 890 b C | 1170 b B | 1730 a A | 1220 a B | 81 |
| **11 Dec** | - | - | 1420 a A | 1480 b A | 740 b B | 89 |
| SE | 85 | 85 | 84 | 84 | 102 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD Growth period by planting date interaction ($P < 0.0001$)

Table 4.13 Growth period by planting date interaction for total forage yield in 1997

| Planting date | Growth period<br>Late-fall<br>(8 Nov.-21 Dec.) | <br>Early-winter<br>(22 Dec.-5 Feb.) | <br>Late-winter<br>(6 Feb.-20 Mar.) | <br>Early-spring<br>(21 Mar - 8 May) | <br>Late-spring<br>(9 May - 21 June) | SE |
|---|---|---|---|---|---|---|
| | | | kg DM ha$^{-1}$ | | | |
| 2 Oct | - | - | 720 b B† | 1280 b A | 800 a B | 106 |
| 30 Oct | - | - | 730 b B | 1410 ab A | 900 b B | 111 |
| 25 Nov | - | - | 1050 a B | 1640 a A | 410 b C | 107 |
| 23 Dec | - | - | - | 1390 ab A | 1100 b B | 104 |
| SE | | | 96 | 96 | 126 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Growth period by planting date interaction ($P < 0.0001$)

January. In the present study, although greater total DM yield was achieved with October and November plantings in both years, earlier planting, i.e. late September to early October, may be done in favorable years, when temperatures drop early and soil moisture is good. In this situation some early forage production may be obtained and grazing may start during fall. Soil moisture is the key to successfully growing cool-season forages in Florida (Stanley, 1999b), it along with onset of cool temperatures are the major determinants of successful planting dates.

In the current study, the 19 Sept. 1996 planting presented forage in late fall, but only a small amount, a situation that continued through the winter. Therefore, it could be grazed throughout but only with a very low stocking rate. October and November planting dates presented better overall forage distribution throughout the growing season. The October planting dates presented peaks of production in early winter due to small grains, and in early spring due primarily to ryegrass contribution (Figs. 4.3 and 4.4). The November planting dates had peak forage production in early spring in 1997. The yield for R-O-Rg mixture was high by early spring, more than 2700 kg DM ha$^{-1}$ in 1996, indicating the possibility of increasing stocking rate during this period.

### Nutritive Value

### In vitro organic matter digestion

There was a planting date by mixture interaction (P < 0.0559 and P < 0.0001) for 1996 and 1997 IVOMD, respectively (Tables 4.14 and 4.15). Interaction occurred in 1996 because there was no effect of planting date on IVOMD for R-O-Rg, R-O-Crim, and R-O-Rg-Crim, but for the other mixtures the September planting had the lowest IVOMD

Table 4.14  Planting date by mixture interaction for herbage IVOMD in 1996

| Mixture | Planting date | | | | |
|---|---|---|---|---|---|
| | 19 Sept | 7 Oct | 14 Nov | 11 Dec | SE |
| | g kg$^{-1}$ OM | | | | |
| R-O† | 700 ab B‡ | 742 a A | 750 ab A | 774 a A | 13 |
| R-O-Rg | 696 ab A | 703 b A | 723 a A | 718 a A | 12 |
| R-O-Crim | 683 b A | 671 c A | 684 c A | 681 b A | 11 |
| R-O-Rg-Crim | 715 a A | 698 bc A | 705 ab A | 717 a A | 11 |
| R-O-Red | 674 bc B | 706 b A | 693 bc AB | 701 a AB | 11 |
| R-O-Rg-Red | 666 c B | 709 ab A | 710 ab A | 714 a A | 11 |
| SE | 9 | 11 | 12 | 20 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Means within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction ($P < 0.0559$).

Table 4.15. Planting date by mixture interaction for herbage IVOMD in 1997

| Mixture | Planting date<br>2 Oct | <br>30 Oct | <br>25 Nov | <br>23 Dec | SE |
|---|---|---|---|---|---|
| | g kg$^{-1}$ OM | | | | |
| R-O† | 742 b AB‡ | 742 b AB | 756 ab A | 713 b B | 10 |
| R-O-Rg | 751 b A | 759 ab A | 744 b AB | 726 b B | 6 |
| R-O-Crim | 681 c B | 686 c B | 676 d B | 730 ab A | 11 |
| R-O-Rg-Crim | 740 b A | 721 b B | 752 ab A | 750 a A | 7 |
| R-O-Red | 744 b AB | 754 ab A | 724 c C | 727 ab BC | 6 |
| R-O-Rg-Red | 773 a A | 768 a A | 761 a A | 736 ab B | 6 |
| SE | 7 | 7 | 7 | 10 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction ($P < 0.0001$).

(Table 4.14). A major cause of interaction in 1997 was that R-O-Crim had low IVOMD for the first three planting dates but high IVOMD for the last one (Table 4.15). Mixture IVOMD was high averaging 706 and 736 g kg$^{-1}$ OM across treatments for 1996 and 1997, respectively. Mixtures including ryegrass had the highest overall IVOMD for all planting dates in both years, and the greater proportion of ryegrass in the second year likely contributed to trends toward greater IVOMD in that year. Clearly, including ryegrass in the mixture is an important step in achieving high IVOMD.

There was a mixture by growth period interaction ($P < 0.0001$) for IVOMD in both years (Tables 4.16 and 4.17). There were no differences among mixtures in late fall and early winter. The R-O-Rg mixture presented higher digestibility during late winter than mixtures without ryegrass in 1996 (Table 4.16), however in the same growth period in 1997, the mixtures with clover were superior to grass-only mixtures (Table 4.17). Independent of mixture, IVOMD was very high. It varied from 720 to 832 g kg$^{-1}$ OM during fall and winter. Although IVOMD decreased from late winter to late spring, it remained above 600 g kg$^{-1}$ OM during early spring and above 540 g kg$^{-1}$ OM in late spring due to ryegrass and red clover components. Thus, the presence of ryegrass or clover may both extend the grazing season and improve late-season IVOMD (Figs. 4.3 and 4.4, and Table 4.18). According to Lippke and Ellis (1997), clover and ryegrass forage in vegetative stages of growth usually have digestibility values greater than 700 g kg$^{-1}$ DM, approaching and sometimes exceeding 800 g kg$^{-1}$ DM in the first weeks of the growing season. The decline in digestibility in red clover is associated with an increasing lignin concentration and a reduction in degradability of polysaccharides other than starch

Table 4.16. Growth period by mixture interaction for herbage IVOMD in 1996. Data are averaged across four planting dates.

| Mixture | Growth period | | | | | |
|---|---|---|---|---|---|---|
| | Late-fall<br>(8 Nov.-21 Dec.) | Early-winter<br>(22 Dec.-5 Feb.) | Late-winter<br>(6 Feb.-20 Mar.) | Early-spring<br>(21 Mar.-8 May) | Late-spring<br>(9 May-21 June) | SE |
| | ---------- | ---------- | ---------- g kg$^{-1}$ OM | ---------- | ---------- | |
| R-O† | 801 a A‡ | 780 a A | 724 b B | 662 abc C | - | 14 |
| R-O-Rg | 767 a A | 778 a A | 762 a A | 683 a B | 560 a C | 14 |
| R-O-Crm | 767 a A | 754 a A | 720 b B | 616 d C | 542 b D | 13 |
| R-O-Rg-Crm | 762 a A | 771 a A | 746 ab A | 670 ab B | 594 a C | 11 |
| R-O-Red | 752 a AB | 765 a A | 723 b B | 636 cd C | 593 a D | 13 |
| R-O-Rg-Red | 776 a A | 766 a A | 743 ab A | 637 cd B | 578 a C | 13 |
| SE | 23 | 12 | 10 | 10 | 10 | |

† R = rye, O = oat, Rg = ryegrass, Crm = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Growth period by mixture interaction ($P < 0.0001$).

Table 4.17. Growth period by mixture interaction for herbage IVOMD in 1997. Data are averaged across four planting dates.

| Mixture | Growth period | | | | | |
|---|---|---|---|---|---|---|
| | Late-fall | Early-winter | Late-winter | Early-spring | Late-spring | |
| | (8 Nov - 21 Dec.) | (22 Dec - 5 Feb.) | (6 Feb - 20 Mar.) | (21 Mar. - 8 May) | (9 May - 21 June) | SE |
| | g kg$^{-1}$ OM | | | | | |
| R-O† | - | - | 789 b A‡ | 688 c B | - | 8 |
| R-O-Rg | - | - | 785 b A | 789 ab A | 661 a B | 7 |
| R-O-Crim | - | - | 832 a A | 697 c B | 551 c C | 7 |
| R-O-Rg-Crim | - | - | 820 a A | 759 b B | 643 b C | 8 |
| R-O-Red | - | - | 822 a A | 720 b B | 670 a C | 8 |
| R-O-Rg-Red | - | - | 817 a A | 804 a A | 659 a C | 8 |
| SE | | | 9 | 7 | 5 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different (P > 0.05) by LSD. Growth period by mixture interaction (P < 0.0001)

Table 4 18 Average IVOMD and CP concentration for botanical components of cool-season forage mixtures during five growth periods in 1996 and 1997

| IVOMD | Botanical component | Growth period | | | | |
|---|---|---|---|---|---|---|
| | | late-fall | early-winter | late-winter | early-spring | late-spring |
| | | g kg$^{-1}$ OM | | | | |
| 1996 | Rye | 733 | 671 | 623 | - | - |
| 1997 | | - | - | 763 | - | - |
| 1996 | Oat | 728 | 666 | 659 | - | - |
| 1997 | | - | - | 762 | 712 | - |
| 1996 | Ryegrass | 766 | 771 | 727 | 684 | 662 |
| 1997 | | - | - | 843 | 760 | 678 |
| 1996 | Crimson | - | - | 689 | 605 | 568 |
| 1997 | clover | - | - | 767 | 622 | - |
| 1996 | Red | - | - | 774 | 741 | 636 |
| 1997 | clover | - | - | 804 | 729 | 720 |

| CP | Botanical component | Growth period | | | | |
|---|---|---|---|---|---|---|
| | | late-fall | early-winter | late-winter | early-spring | late-spring |
| | | g kg$^{-1}$ DM | | | | |
| 1996 | Rye | 190 | 144 | 143 | 93 | - |
| 1997 | | - | - | 116 | 127 | - |
| 1996 | Oat | 208 | 187 | 156 | 102 | - |
| 1997 | | - | - | 108 | 131 | - |
| 1996 | Ryegrass | 223 | 175 | 144 | 107 | 121 |
| 1997 | | - | - | 123 | 117 | 138 |
| 1996 | Crimson | - | - | 209 | 157 | 139 |
| 1997 | clover | - | - | 218 | 182 | - |
| 1996 | Red | - | - | 236 | 220 | 191 |
| 1997 | clover | - | - | 246 | 231 | 252 |

(Taylor and Quesenberry, 1996). Despite this red clover IVOMD was about 700 g kg$^{-1}$ OM during spring (Table 4.18).

There was a planting date by growth period interaction ($P < 0.0001$) on herbage IVOMD for both years (Tables 4.19 and 4.20). Herbage IVOMD decreased from winter to late spring. The IVOMD of early-spring herbage for 1996 plantings increased as planting was delayed (Table 4.19). There was no planting date effect on herbage IVOMD for late-spring in 1996, however IVOMD of October 1997 plantings was greater in late spring than November and December 1997 plantings (Tables 4.19 and 4.20), perhaps due to greater clover contribution in this period (Fig. 4.4).

Crude protein

The planting date by mixture interaction was significant ($P < 0.03$) for CP in both years (Tables 4.21 and 4.22). Forage CP was always above 125 g kg$^{-1}$ DM in 1996 and above 98 g kg$^{-1}$ OM in 1997. Lowest values were usually associated with late planting dates, and CP was lower in 1997 than 1996 due in part to high rainfall in the second year and probable leaching losses of N as well as advanced maturity at first harvest. Trends among mixtures were not consistent across dates or years.

The growth period by mixture interaction was significant ($P < 0.0001$) for CP in both years (Tables 4.23 and 4.24). The mixtures maintained CP concentration through fall and winter, but after winter the CP concentration decreased dramatically in 1996. Levels in late spring were about 130 g kg$^{-1}$ DM, and were that high due to ryegrass and clover components (Figs. 4.3 and 4.4, Table 4.18). In 1997, herbage CP increased from winter to spring in most mixtures due to advanced maturity at first harvest, but then remained relatively constant in late spring. Red clover was the component with highest CP

Table 4 19 Growth period by planting date interaction for herbage IVOMD in 1996

| Planting date | Growth period<br>Late-fall<br>(8 Nov -21 Dec ) | Early-winter<br>(22 Dec -5 Feb.) | Late-winter<br>(6 Feb.-20 Mar) | Early-spring<br>(21 Mar-8 May) | Late spring<br>(9 May-21 June) | SE |
|---|---|---|---|---|---|---|
| | g kg$^{-1}$ OM | | | | | |
| 19 Sept | 753 B† | 779 b A | 700 b C | 624 c D | 572 a E | 7 |
| 17 Oct | - | 712 c B | 765 a A | 673 a C | 574 a D | 7 |
| 14 Nov | - | 805 a A | 712 b B | 656 ab C | 590 a D | 8 |
| 11 Dec | - | - | 769 a A | 649 b B | 579 a C | 7 |
| SE | 7 | 7 | 7 | 7 | 8 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD Growth period by planting date interaction ($P < 0.0001$)

Table 4 20 Growth period by planting date interaction for herbage IVOMD in 1997.

| Planting date | Growth period<br>Late-fall (8 Nov.-21 Dec.) | Early-winter (22 Dec.-5 Feb.) | Late-winter (6 Feb.-20 Mar.) | Early-spring (21 Mar.-8 May) | Late-spring (9 May-21 June) | SE |
|---|---|---|---|---|---|---|
| | | | g kg$^{-1}$ DM | | | |
| 2 Oct | - | - | 815 ab A† | 734 b B | 679 a C | 7 |
| 30 Oct | - | - | 804 b A | 746 ab B | 679 a C | 7 |
| 25 Nov | - | - | 826 a A | 733 b B | 643 b C | 7 |
| 23 Dec | - | - | - | 758 a A | 592 c B | 7 |
| SE | | | 6 | 6 | 8 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Growth period by planting date interaction ($P < 0.0001$).

Table 4.21 Planting date by mixture interaction for herbage crude protein concentration in 1996

| Mixture | Planting date<br>19 Sept. | <br>7 Oct | <br>14 Nov | <br>11 Dec. | SE |
|---|---|---|---|---|---|
| | g kg$^{-1}$ DM | | | | |
| R-O† | 167 a B‡ | 165 a B | 186 a A | 168 a B | 5 |
| R-O-Rg | 163 a A | 146 b B | 168 b A | 148 b B | 4 |
| R-O-Crim | 163 a A | 141 b B | 159 b A | 131 cd B | 4 |
| R-O-Rg-Crim | 157 a A | 143 b A | 148 c A | 130 cd B | 4 |
| R-O-Red | 161 a A | 143 b B | 150 c B | 142 bc B | 4 |
| R-O-Rg-Red | 142 b A | 125 c B | 133 d AB | 126 d B | 4 |
| SE | 4 | 4 | 4 | 5 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction ($P < 0.0232$)

Table 4.22 Planting date by mixture interaction for herbage crude protein concentration in 1997

| | Planting date | | | | |
|---|---|---|---|---|---|
| Mixture | 2 Oct | 30 Oct | 25 Nov | 23 Dec | SE |
| | g kg$^{-1}$ DM | | | | |
| R-O† | 113 b B‡ | 120 b AB | 133 ab A | 98 b B | 8 |
| R-O-Rg | 111 b AB | 122 ab AB | 112 c AB | 105 b B | 5 |
| R-O-Crim | 135 a A | 138 a A | 145 a A | 108 b B | 7 |
| R-O-Rg-Crim | 107 b B | 126 ab A | 122 bc A | 105 b B | 6 |
| R-O-Red | 137 a B | 132 ab AB | 122 bc B | 137 a A | 5 |
| R-O-Rg-Red | 124 a A | 128 ab A | 134 ab A | 98 b B | 5 |
| SE | 6 | 6 | 6 | 7 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Planting date by mixture interaction ($P < 0.0042$)

Table 4.23 Growth period by mixture interaction for herbage crude protein concentration in 1996

| Mixture | Growth period<br>Late-fall<br>(8 Nov - 21 Dec.) | Early-winter<br>(22 Dec -5 Feb.) | Late-winter<br>(6 Feb -20 Mar.) | Early spring<br>(21 Mar - 8 May) | Late-spring<br>(9 May - 21 June) | SE |
|---|---|---|---|---|---|---|
| | g kg⁻¹ DM | | | | | |
| R-O† | 199 a A‡ | 184 a A | 195 a A | 148 a B | - | 8 |
| R-O-Rg | 193 a A | 155 b B | 199 a A | 126 b C | 126 b C | 8 |
| R-O-Crim | 194 a A | 170 ab AB | 162 b B | 132 b C | 128 b C | 7 |
| R-O-Rg-Crim | 171 a A | 157 b AB | 165 b A | 126 b B | 128 b B | 7 |
| R-O-Red | 186 a A | 168 ab A | 160 b A | 123 b B | 145 a B | 7 |
| R-O-Rg-Red | 172 a A | 151 b A | 155 b A | 101 c B | 117 b B | 7 |
| SE | 18 | 20 | 8 | 8 | 10 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different (P > 0.05) by LSD. Growth period by mixture interaction (P < 0.0001)

Table 4.24 Growth period by mixture interaction for herbage crude protein concentration in 1997

| Mixture | Growth period<br>Late-fall<br>(8 Nov.-21 Dec.) | <br>Early-winter<br>(22 Dec.-5 Feb.) | <br>Late-winter<br>(6 Feb - 20 Mar.) | <br>Early-spring<br>(21 Mar. - 8 May) | <br>Late-spring<br>(9 May - 21 June) | SE |
|---|---|---|---|---|---|---|
| | | | $g\ kg^{-1}$ DM | | | |
| R-O† | - | - | 87 b B‡ | 122 ab A | | 6 |
| R-O-Rg | - | - | 88 b C | 107 c B | 135 b A | 5 |
| R-O-Crim | - | - | 108 ab B | 136 a A | 119 bc AB | 8 |
| R-O-Rg-Crim | - | - | 111 a A | 120 b A | 105 c A | 5 |
| R-O-Red | - | - | 112 a B | 117 bc B | 161 a A | 5 |
| R-O-Rg Red | - | - | 97 b C | 118 b B | 138 b A | 5 |
| SE | | | 6 | 5 | 7 | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Growth period by mixture interaction ($P < 0.0001$)

concentration (Table 4.18). The growth period by planting date interaction was significant ($P < 0.0001$) for CP concentration in both years (Tables 4.25 and 4.26). Generally December plantings presented lower CP concentration than earlier plantings. Also, CP concentration was improved or at least maintained from early spring to late spring due to ryegrass and especially clovers (Table 4.18). The legumes had a lower rate of decrease in nutritive value during spring compared with grasses. Lappke and Ellis (1997) estimated CP concentration of these forages to range from 200 to 300 g kg$^{-1}$ DM.

The higher nutritive value of ryegrass and clovers in late spring 1998 may be due to drought. Peterson et al. (1992) found higher digestibility in plants due to moderate moisture stress than in control irrigated plants. In addition some plant characteristics account for a higher nutritive value of stressed plants, such as higher leaf/stem ratio and delayed maturity.

## Summary and Conclusions

A 2-yr experiment was conducted at the Beef Research Unit, University of Florida, Gainesville. The objective was to determine the effect of planting date on forage yield, forage distribution, and nutritive value of six cool-season forage mixtures. Four planting dates at 4-wk intervals were tested from September to December of 1996 and 1997. The mixture treatments were a) R-O (rye cv. Grazemaster, and oat cv. Ozark), b) R-O-Crim (rye, oat, and crimson clover cv. Dixie), c) R-O-Red (rye, oat, and red clover cv. Cherokee), and each of these treatments with ryegrass cv. Surrey. Treatments were

Table 4.25. Growth period by planting date interaction for herbage crude protein in 1996.

| Planting date | Growth period | | | | | |
|---|---|---|---|---|---|---|
| | Late-fall (8 Nov -21 Dec) | Early-winter (22 Dec -5 Feb) | Late-winter (6 Feb - 20 Mar) | Early-spring (21 Mar -8 May) | Late-spring (9 May- 21 June) | SE |
| | ---------------------- | ---------------------- | g kg$^{-1}$ DM | ---------------------- | ---------------------- | |
| 19 Sept | 190 A† | 142 c B | 186 a A | 129 ab C | 147 a B | 4 |
| 17 Oct | - | 154 b A | 157 c A | 139 a B | 124 b B | 4 |
| 14 Nov. | - | 201 a A | 169 b B | 120 bc D | 141 a C | 4 |
| 11 Dec | - | - | 118 d A | 116 c A | 128 b A | 4 |
| SE | 4 | 4 | 4 | 4 | 5 | |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD. Growth period by planting date interaction ($P < 0.0001$)

Table 4.26 Growth period by planting date interaction for herbage crude protein in 1997

| Planting date | Growth period |  |  |  |  |  |
|---|---|---|---|---|---|---|
|  | Late-fall (8 Nov -21 Dec ) | Early-winter (22 Dec -5 Feb ) | Late-winter (6 Feb -20 Mar ) | Early-spring (21 Mar -8 May) | Late-spring (9 May-21 June) | SE |
|  | $g\ kg^{-1}$ DM |  |  |  |  |  |
| 2 Oct | - | - | 98 a C† | 118 ab B | 148 a A | 5 |
| 30 Oct | - | - | 112 a B | 129 a A | 143 a A | 5 |
| 25 Nov | - | - | 109 a B | 122 ab B | 153 a A | 5 |
| 23 Dec | - | - | - | 112 b A | 105 b A | 5 |
| SE |  |  | 4 | 4 | 6 |  |

† Values within a column followed by the same lower case letter or in the same row followed by the same upper case letter are not different ($P > 0.05$) by LSD Growth period by planting date interaction ($P < 0.0001$)

arranged as a split-plot experiment in four replicates of a randomized complete block design with planting date as the main plot and forage mixture as the sub-plot. Plots were sampled when forage was 25- to 40-cm tall using a sickle-bar mower to cut to a 7- to 10-cm stubble height. Total forage yield, forage botanical composition and components of yield, and total and component nutritive value were measured. To assess seasonal distribution of dry matter, harvests were grouped into five growth periods designated late fall, early winter, late winter, early spring, and late spring.

The R-O-Rg mixture was highest yielding in both years and R-O-Crim was equal to R-O-Rg in 1996. All mixtures had higher yields in 1996 than in 1997 due to excessive winter/spring rains in the latter year, but yields of mixtures with ryegrass decreased less during 1997 than those without ryegrass. October and November plantings resulted in greater DM yield than earlier or later plantings for most mixtures, but the R-O mixture tended to have greatest yield when planted in September.

Small grain was the most important botanical component for all mixtures in 1996 (dry late winter-early spring). Ryegrass supplanted small grains in 1997 (wet winter). Clover was quantitatively important and had a greater contribution in mixtures without ryegrass. Crimson clover represented a greater proportion of the DM yield in the driest year and red clover in the wet year.

Only when planting occurred in September was there a harvest during the late fall (before 21 December) growth period. First harvest was delayed as planting date was postponed. Fall and winter forage production from rye-oat was greater than from ryegrass whereas spring forage production was greater for ryegrass and clovers. The R-O mixture extended DM production through no later than early spring (21 March to 8 May). Mixtures including clover tended to produce significant forage after 8 May (late spring), and clovers were primarily responsible for extending DM yield. The greatest clover yield in late spring was achieved either by delaying planting of mixtures with crimson clover or by using red clover in mixtures. Delaying until December to plant was too long as mixtures from this date had lowest clover yield during late spring in both years. Adding ryegrass to the R-O mixture extended the grazing season, but in mixtures including clover, the main contribution of ryegrass was to increase forage production more than to extend the season of growth. The clover component was primarily responsible for extending the growth season, with crimson clover extending production to mid-May and red clover throughout May.

Herbage IVOMD was high averaging more than 700 g $\mathrm{kg^{-1}}$ OM across treatments. The IVOMD decreased from late winter to late spring harvests. Mixtures including ryegrass had the highest overall IVOMD for all planting dates in both years, therefore including ryegrass in the mixtures was an important step in achieving high IVOMD. The IVOMD of spring herbage from October plantings was often the greatest or nearly the greatest in IVOMD.

December plantings generally had lowest herbage CP concentration. The mixtures maintained high CP concentration (>160 g $\mathrm{kg^{-1}}$ DM) during fall and winter. Despite the CP concentration declining to about 130 g $\mathrm{kg^{-1}}$ DM during late spring, it remained at this level primarily due to ryegrass and clover components.

Cool-season annual grasses with clovers will likely be an important component of economical year-round forage systems for grazing by dairy cows in Florida. Forage distribution and forage nutritive value can be improved by growing these species in systems based on warm-season perennial grasses. Legumes in mixed pastures may reduce N fertilizer because through grazing, nutrients from feces and urine are distributed and recycled to produce more forage, potentially reducing environmental impact. The combination of planting date and especially choice of appropriate mixtures of small grains, ryegrass, and clovers may allow production of forage for grazing from late-December/early January to May (5 mo), a period in which perennial warm-season grasses lack both the production and nutritive value necessary for lactating dairy cows.

# CHAPTER 5
# DAIRY COW PERFORMANCE ON PASTURE-BASED FEEDING SYSTEMS AND IN CONFINEMENT

## Introduction

Milk production based on intensively managed pasture is a fast growing production system in the USA and Ireland, and has been important in New Zealand for many years (Hanson et al., 1998b). The key concept is substituting the cow for expensive machinery in the harvest of forages. These authors proposed that lower production costs are the primary economic benefit of intensive grazing compared to traditional systems based on mechanized harvesting and forage conservation. Interest in grazing systems is growing among farmers in all parts of the USA as a means of increasing profits (Bertrand, 1998). Staples et al. (1994) list several reasons for greater interest in grazing including: a) lower expenses for feed, equipment, and buildings potentially leading to greater income per cow, b) reported improvements in animal health and reproduction (less culling), c) growing pressure from regulatory agencies and environmental interests to reduce a centralized accumulation of cattle wastes, and d) improved quality of life for managers (less stress, more leisure time).

Grazing lactating dairy cows on pasture is not a new feeding method. This approach was advocated, abandoned, and now is being advanced again as an alternative feeding system, particularly in the northeastern USA. After World War II, many dairy farmers in the USA moved away from grazing as a primary source of nutrients for cattle to mechanized feeding systems supported by inexpensive energy fuels and advances in mechanization, fertilizers, and pesticides (Bertrand, 1998)

In a historical review, Hanson et al. (1998a) detailed these changes By the late-1940s, farmers began to significantly increase their application of manufactured inputs, particularly purchased fertilizers herbicides, and hybrid corn (*Zea mays* L.) seed. Between the late-1940s and 1990s, farmers achieved more than a two-fold increase in yield of row crops such as corn and soybean (*Glycine max* [L.] Merr ), mainly due to new cultivars and use of purchased inputs Advances associated with feeding technology pushed management toward feeding/finishing livestock in confinement Within this context, the pasture was viewed as a low-yield source of supplemental forage or as an exercise lot. Muller and Holden (1994) described these changes in the Pennsylvania dairy industry where the average number of cow days on pasture decreased from 170 in the early 1950s to 64 in 1990 However during the 1980s, the increasing perception of negative effects of dairy cows wastes on the environment (Russelle et al., 1997), rising costs of machinery and housing, and reduced profit margin (Parker et al., 1992) began to make pasture systems more attractive

The system that has evolved in many areas of the USA during the 1980s and 1990s maintains an emphasis on concentrate feeding and high milk production but with most forage coming from grazed pasture. In contrast, the New Zealand system is centered around the use of grazing in combination with seasonal dairying and minimal feeding of grain in the ration, i.e., low production costs that permit a globally competitive milk price (Holmes and Wilson, 1987) The cost of producing milk in the USA and Canada are

300% of those in New Zealand. A reason for that is the New Zealand climate which allows grass to grow and be grazed 12 mo of the year (Murphy, 1993)

In addition to lower production costs, another benefit of a pasture-based dairy system is the potential reduction of soil erosion; this has been calculated to be 80 to 90% less with pasture than with production of oats (*Avena sativa* L.), corn silage, or corn grain (USDA, 1989). The use of fertilizer and other inputs increase as animal stocking rates increase, however, poorly managed pasture can cause soil erosion and loss of nutrients to the environment (Owens et al., 1983)

Most Florida dairy farms have large herds (average of 600 cows) that traditionally have occupied relatively small land areas per farm. Typically these farms produce little of their own feed, rely heavily on concentrate feeds and byproduct fiber sources, and have limited or no use of grazed pasture by the lactating herd. Despite inherently high feed costs, this system has been profitable due to relatively high and stable milk prices. In recent years, increasing production costs and more widely fluctuating milk prices have stimulated some interest in alternative production systems of lower costs and greater emphasis on home-grown forage as a feed source. Additionally, state regulations require that nutrients in animal wastes be used for crop production on farm, making forage production more attractive. Intensive grazing of pastures by dairy cows may be an economically viable alternative to conventional systems of confined housing of cows and feeding of preserved forages. Use of pasture-based dairy systems is challenging in Florida, however, because of varying nutritive value of forage throughout the year, heat stress, and the difficulty in formulating balanced rations due to problems of quantifying forage intake on pasture

Most research done with pasture-based systems has been short term in nature. Longer, full-lactation comparisons of pasture and confinement systems are needed. In addition, previous Florida studies (Fike et al., 1997a,b) have shown large declines in milk production of mid-lactation cows moved from confinement housing to summer pastures. These data suggest that there may be advantages to freshening cows in fall and early winter, assigning them to high quality cool-season pasture for the first four months or more of their lactation, and matching periods of peak production and cool temperatures. This experiment was conducted to compare pasture-based and confinement systems for lactating dairy cows over a period from January to October 1998. Objectives were: 1) to compare milk production and composition from pasture-based systems for lactating dairy cows with those of conventional confinement housing system, and 2) to compare feeding costs per unit of milk produced for the two pasture systems and a conventional confinement housing system.

## Material and Methods

The experiment was performed at the University of Florida Dairy Research Unit (DRU) in Hague, which is located about 20 km north of Gainesville, Florida (30° N latitude and 82.5°W longitude). Soils are a composite of four fine sands belonging to the Fort Meade Series (hyperthermic, Quartzipsammentic Haplumbrepts), the Tavares Series (hyperthermic, uncoated, Typic Quartzipsamments), the Chipley Series (thermic, coated, Aquic Quartzipsamments), and the Monteocha Series (hyperthermic, ultic Haplaquods), (USDA,1985). In general, the soils of the DRU are of medium to high fertility and vary from moderately well drained to very poorly drained. Soil test analyses for 1998 showed a pH of 5.7, and Mehlich I extractable P of 116 g $kg^{-1}$, K of 40 g $kg^{-1}$, Mg of 46 g $kg^{-1}$, and Ca of 400 g $kg^{-1}$.

Procedures

The three treatments were two pasture systems and a traditional free-stall housing management. Pasture System 1 was designed to utilize the highest quality annual forages for grazing that are available in the region. Pasture System 2 was intended to reflect less intensive management, utilizing a perennial grass for warm-season grazing and annual grasses for the cool season. Both pasture systems were replicated four times in a randomized block design. Pasture size for each experimental unit was 1.2 ha with 0.8 ha of this area being grazed during winter-spring and 0.4 ha being grazed during summer-fall. Three multiparous Holstein cows were assigned to each pasture system for a base stocking rate of 3.75 cows per hectare during winter and 7.5 cows per hectare during summer, and a total of 12 cows per pasture system. Sixteen cows were assigned to serve as controls in the free-stall facility, for a total of 40 cows in the experiment.

System 1 was based on a mixture of 'Grazemaster' rye (*Secale cereale* L.), 'Surrey' annual ryegrass (*Lolium multiflorum* Lam.), 'Flame' crimson clover (*Trifolium incarnatum* L.), 'Cherokee' red clover (*Trifolium pratense* L.) during the winter-spring season, and 'Tifleaf 2' pearl millet (*Pennisetum glaucum* [L.] R.Br.) during the summer-fall season. System 2 utilized rye-ryegrass mixtures (no clover) during winter-spring and 'Tifton 85' bermudagrass (*Cynodon spp*.) during summer-fall. Concurrently, Holstein cows managed in free-stall housing at the university farm comprised System 3.

Pasture Establishment and Management

The cool-season annual forages were planted on 23 to 24 Oct. 1997, by sod-seeding one replicate over bermudagrass and three replicates over 'Florigraze' rhizoma peanut (*Arachis glabrata* Benth.) pastures without use of herbicide. The seeding rates for the System 1 were 68 kg ha$^{-1}$ for rye, 11.4 kg ha$^{-1}$ for ryegrass, 10 kg ha$^{-1}$ for crimson clover, and 6 kg ha$^{-1}$ for red clover. The clovers were inoculated with *Rhizobium trifolli*. The seeding rates for the System were 91 kg ha$^{-1}$ for rye and 17 kg ha$^{-1}$ for ryegrass. Irrigation was used as needed to ensure good stand establishment. Cows were assigned at calving to treatments in January and February, 1998. Initiation of the study at this time combined cool weather and forages of highest quality with the early postpartum period, that time of the lactation cycle when demand for energy is greatest.

Winter pastures were stocked at 3.75 cows per hectare during the majority of the season based on previous work by Macoon et al. (1997). Because of limitations on availability of fresh cows, grazing was initiated at a stocking rate of 2.5 cows per hectare. As cows calved and forage production increased, the stocking rate was increased to 3.75 cows per hectare in late January. Cows on both pasture systems were moved to a new paddock daily and the rest period between grazings for a given paddock was 28 d.

For each replicate of System 1, pearl millet was seeded on 20 May at 25 kg ha$^{-1}$. Before planting the area was sprayed using 5.0 L ha$^{-1}$ of Roundup® (Monsanto Co., St. Louis, MO, Glyphoate, N-phosphonomethyl glycane in the form of its isopropylamine salt, 1%) to kill bermudagrass (*Cynodon dactylon* [L.] Pers.). Selection of Tifleaf 2 was based upon 2 yr of experiments (1996 and 1997) that compared a group of pearl millet and sorghum-sudangrass cultivars under frequent defoliation (Chapter 3). Irrigation was used as needed and grazing was begun on 16 June when pearl millet reached a height of 40 cm. For System 2, well-established stands of the summer perennial Tifton 85 bermudagrass were available for grazing when growth began in late spring. Cows transitioned from winter to summer pastures in early June and grazed summer pastures until early October The stocking rate of 7 5 cows ha$^{1}$ was chosen for summer pastures as based on data from Fike et al. (1997) and Sollenberger et al. (1995) Target stubble heights for bermudagrass and pearl millet were 20 and 15 cm, respectively Cows in both systems were moved to a new paddock daily and the rest period between grazings was 21 d.

Pasture Fertilization

Pasture fertilization was guided by soil tests, previous experience at this location, and need for forage Fertilization rates and date are summarized in Table 5 1 The total amount applied in each system was 280-17-99 kg ha$^{1}$ of N-P-K, respectively, on system 1 (rye-ryegrass-clovers/pearl millet) and 360-17-99 on System 2 (rye-ryegrass/ bermudagrass) In addition two extra applications of 40 kg N ha$^{1}$ were made for System 2 in late spring and in late summer Although System 1 included clover, previous experience has shown that early-season growth of rye and ryegrass planted in association with clover slow if no N fertilizer is applied

Table 5 1. Fertilization rates and dates of application on pasture systems.

| Date | System 1 Rye-ryegrass-clovers/ pearl millet | | | System 2 Rye-ryegrass/ bermudagrass | | |
|---|---|---|---|---|---|---|
| | N | P | K | N | P | K |
| | kg ha$^{-1}$ | | | | | |
| 12 Nov | 40 | - | - | 40 | - | - |
| 19 Dec | 40 | - | 33 | 40 | - | 33 |
| 10 Feb | 40 | - | - | 40 | - | - |
| 5 Mar | 40 | - | - | 40 | - | - |
| 14 Apr | - | - | - | 40 | - | - |
| 10 June | 40 | 17 | 66 | 40 | 17 | 66 |
| 9 July† | 40 | - | - | 40 | - | - |
| 13 Aug | 40 | - | - | 40 | - | - |
| 10 Sep | - | - | - | 40 | - | - |
| Total | 280 | 17 | 99 | 360 | 17 | 99 |

† N source was ammonium nitrate on all dates but 9 July when ammonium sulphate was applied

Animal Use and Management

A total of 40 multiparous Holstein cows were assigned randomly at calving to the three treatments during about a 30-d period, 24 cows were assigned to the two pasture systems and 16 cows assigned to serve as controls in the free-stall facility. Water was available in ad libitum amounts in the paddocks. Cows and water troughs were moved to a fresh paddock after the morning milking. Portable shades were provided in the summer.

Supplement was fed at a rate of 1 kg as-fed per 2.5 kg of milk produced during winter and 1 kg as-fed per 2 kg of milk produced in summer. Supplement was fed in each paddock to the 3 cows as a group. Amount fed were adjusted twice weekly. Representative samples of supplements were collected weekly, composited monthly, and analyzed chemically by Forage One (Ithaca, NY). Average chemical composition of the concentrate supplements and mineral composition of herbage are summarized in Tables 5.2 and 5.3, respectively. During those weeks in late spring (from 26 May to 16 June) when winter forages were diminishing and summer forages were not ready to graze, cows were fed a cottonseed hull-based ration to ensure that dry matter intake was not limiting (18 kg cow$^{-1}$ d$^{-1}$ as-fed) and to manage body condition. This procedure was repeated for System 1 (pearl millet) from 6 September, on two replicates, and from 18 September, on all four replicates, to the end of the experiment (7 Oct. 1998). During this period the amount fed was 16.4 kg (as-fed) cow$^{-1}$ d$^{-1}$. From 19 February to 19 March, cows on one replicate of both systems were fed corn silage (9 kg of silage as-fed cow$^{-1}$ d$^{-1}$) because excessive soil moisture on that replicate resulted in poor rye growth and low herbage mass. Also corn silage (11 kg of silage as-fed cow$^{-1}$ d$^{-1}$) was fed from 28 April to 18 May to cows of replication III of System 2 (Rye-ryegrass) due to a shortage of forage in that specific field.

Table 5.2 Average chemical composition on DM-basis of TMR (total mixed ration) and concentrate supplement for confined housing and grazing cows.

| Component | TMR | SE | Grazing Systems† | SE | One-shot‡ | SE |
|---|---|---|---|---|---|---|
| NDF, % of DM | 44.9 | 3.71 | 36.4 | 1.81 | 45.6 | 0.42 |
| ADF, % of DM | 30.0 | 3.26 | 24.7 | 2.04 | 36.4 | 1.27 |
| Fat, % of DM | 5.8 | 0.44 | 7.3 | 0.35 | 6.35 | 0.07 |
| NEL, Mcal kg$^{-1}$ of DM | 1.4 | 0.03 | 1.8 | 0.05 | 1.7 | 0.00 |
| CP, % of DM | 16.3 | 0.85 | 17.5 | 0.67 | 17.5 | 0.99 |
| UIP, % of DM | 5.7 | 0.30 | 6.1 | 0.23 | 6.15 | 0.35 |
| DIP, % of DM | 10.6 | 0.56 | 11.4 | 0.43 | 11.35 | 0.64 |
| Sol. CP, % of DM | 5.7 | 0.30 | 6.1 | 0.23 | 6.15 | 0.35 |
| Ca, % of DM | 1.03 | 0.12 | 1.13 | 0.13 | 0.77 | 0.11 |
| P, % of DM | 0.47 | 0.05 | 0.64 | 0.06 | 0.44 | 0.00 |
| K, % of DM | 1.54 | 0.12 | 1.25 | 0.08 | 1.24 | 0.05 |
| Mg, % of DM | 0.32 | 0.02 | 0.52 | 0.05 | 0.34 | 0.01 |
| Na, % of DM | 0.39 | 0.05 | 0.86 | 0.07 | 0.58 | 0.12 |
| S, % of DM | 0.18 | 0.05 | 0.18 | 0.01 | - | - |
| Cl, % of DM | 0.54 | 0.12 | 0.42 | 0.06 | 0.34 | 0.00 |
| Mn, mg kg$^{-1}$ of DM | 70 | 12.8 | 59 | 10.4 | 40 | 3.53 |
| Fe, mg kg$^{-1}$ of DM | 344 | 100 | 403 | 62 | 290 | 17.8 |
| Cu, mg kg$^{-1}$ of DM | 25 | 7.2 | 20 | 6.2 | 14 | 7.8 |
| Zn, mg kg$^{-1}$ of DM | 80 | 14.4 | 110 | 12.4 | I | 13.4 |

†Average from January to September

‡Average of winter and summer

**Table 5.3** Average herbage nutritive value and mineral composition of handplucked samples, within seasons, on pasture systems for grazing

| | Rye-ryegrass-clover | | Pearl millet | Bermuda |
|---|---|---|---|---|
| Mineral | Jan. to Mar | Apr. to May | | grass |
| IVOMD, g kg$^{-1}$ OM | 787 | 703 | 681 | 652 |
| CP, g kg$^{-1}$ DM | 268 | 221 | 223 | 190 |
| NDF, g kg$^{-1}$ DM | 441 | 516 | 586 | 726 |
| Calcium, % of DM | 0.61 | 0.84 | 0.61 | 0.41 |
| Phosphorus, % of DM | 0.54 | 0.41 | 0.63 | 0.36 |
| Potassium, % of DM | 2.97 | 2.11 | 2.44 | 1.85 |
| Magnesium, % of DM | 0.23 | 0.28 | 0.40 | 0.22 |
| Sodium, % of DM | 0.024 | 0.064 | 0.011 | 0.024 |
| Sulfur, % of DM | 0.26 | 0.22 | 0.29 | 0.31 |
| Chlorine, % of DM | 0.92 | 0.57 | 0.80 | 0.50 |
| Manganese, mg kg$^{-1}$ DM | 54 | 45 | 62 | 50 |
| Iron, mg kg$^{-1}$ DM | 66 | 59 | 84 | 82 |
| Cooper, mg kg$^{-1}$ DM | 4 | 4 | 10 | 6 |
| Zinc, mg kg$^{-1}$ DM | 40 | 43 | 44 | 35 |
| Molybdenum, mg kg$^{-1}$ DM | 1.8 | 1.9 | 2.1 | <1.0 |

### Pasture Sampling

Every 3 wk throughout the experiment when pasture was available, pasture samples were taken before and after grazing at six, 0.5-$m^2$ sites that represented average paddock herbage mass. For winter species and bermudagrass, the plants were clipped to a 2.5-cm stubble height, whereas pearl millet was clipped to a 10-cm stubble height. A total of 12 sampling date were used, seven during winter/spring and five during summer/fall. Herbage allowance calculations were based on total pregraze herbage mass. At the time of pregraze sampling, hand-plucked samples were taken by severing herbage at the estimated height of the residual forage left by cows on the paddock grazed 1 d before the sampling date. Herbage was collected at 20 to 30 locations per paddock, composited, and used to determine crude protein (CP), in vitro organic matter digestibility (IVOMD), and neutral detergent fiber (NDF). An additional hand-plucked sample was taken twice in winter from each paddock to determine botanical composition. The components were separated into rye, ryegrass, clovers, and weeds. Hand-plucked samples and forage specie components were dried at 65°C and ground to pass a 1-mm screen using a Wiley mill. Samples were digested for N determinations using a modification of the aluminum block digestion procedure of Gallaher et al. (1975). Ammonia in the digestate was determined by semi-automated colorimetry (Hambleton, 1977), and CP (DM basis) was calculated as N x 6.25. In vitro organic matter digestion was performed by a modification of the two-stage technique (Moore and Mott, 1974). Neutral detergent fiber was determined using the procedure of Golding et al. (1985). Laboratory analyses were conducted in the Forage Evaluation Support Laboratory of the University of Florida.

### Insecticide

On 31 Aug. 1998, fall armyworm (*Spodoptera frugiperda* [J E Smith]) were controlled using an insecticide solution with 2 38 L ha$^{-1}$ of Sevin®, 41% (Rhone-Poulenc) The compound (1-naphthyl-N-methyl carbamate) is a reversible cholinesterase inhibitor, and was chosen because it is safe to mammals and has an acute oral LD 50 greater than 500 mg kg$^{-1}$ body weight (Terrnie, 1982).

### Animal Measurements

Milk production was measured at each of two milkings and milk composition (two consecutive milkings collected weekly) Milk samples of consecutive morning and evening milkings were taken weekly during the first 19 wk of the experiment and biweekly thereafter Milk samples were analyzed for fat, protein, urea nitrogen, and somatic cell count at the Southeastern Dairy Herd Improvement Laboratory in McDonough, GA. Cows were weighed and body condition scored weekly after morning milking

Feed intake of individual cows in free stalls was measured daily using the Calan gate system (American Calan Inc ) Voluntary forage intake by cows on pasture was measured once during winter (average of 81 d in milk) and once during summer (178 d in milk) using a pulse dose technique (Pond et al., 1987, Pond et al.,1989a,b) with chromium-mordanted fiber as an inert marker to determine fecal output Forage of quality similar to that consumed was collected across all pastures and composited. Forages were dried at 65°C and ground to pass a 2-mm screen using a Wiley mill. Fiber from the forage was mordanted using the methodology of Udén et al. (1980) The ground forage (~700g) was wetted with water (1 L of $H_2O$ per 100g of forage) plus 50 ml of liquid laundry detergent. After boiling for 2 h, the forage was washed repeatedly with tap water to remove all soap, rinsed with acetone, dried at 105°C, and weighed. The dried forage was placed in a metal container, and sodium dichromate, dissolved in four volumes (approximately 4 L) of water, was added to the forage. Addition of Cr (as sodium dichromate) equaled 7% of the fiber DM. This slurry was sealed with aluminum foil and heated in a forced-air drying oven at 105°C for 24 h. The liquid was then poured off and the fiber was gently rinsed with tap water to remove excess and unbound Cr. Ascorbic acid (Aldrich®, Milwaukee, WI) at half the weight of dry fiber was mixed with water, added to the fiber, and allowed to stand for 1 to 1.5 h. The fiber was rinsed throughly with tap water and dried at 105°C. Two and one-half ± 0.01 grams (as-is) of mordanted fiber were weighed into 28-g gelatin capsules (Jorgenson Laboratories, Loveland, CO).

The cows were orally pulse-dosed with twelve gelatin capsules containing Cr-mordanted fiber (30 g, as-fed) from their respective forage assignments. Capsules were administered with a multiple dose balling gun (Nasco, Ft. Atkinson, WI) at about 18 h, after the evening milking. Samples of feces were collected at approximately 0, 12, 15, 18, 21, 24, 27, 36, 42, 48, 60, 72 and 84 h post-dosing. Most samples were collected in holding pens at the milking parlor. Samples were collected on pasture for hours 15, 18, 21, 27 and 42. Fecal samples were refrigerated immediately after collection. All fecal samples were dried at 65°C for at least 48 h and ground through a 1-mm screen with a Wiley mill. Samples (2 g, as-is) were dried at 105°C and ashed at 550°C for determination of DM and OM (AOAC, 1990). Ash was digested in a solution of $H_3PO_4$-$MnSO_4$ (30 ml of 10%, w/v, $MnSO_4 \cdot 4H_2O$ + 970 ml of 85% $H_3PO_4$ and $KBrO_3$ solution [90 g per 2 L distilled $H_2O$] using heat on a hot plate till no longer effervescent (no bubbles). When the solution became purple it was poured off into a volumetric flask with 6.25 ml CaCl$_2$ (14.69 g CaCl$_2$ 2 H$_2$O) per liter of distilled H$_2$O and analyzed for Cr by atomic absorption spectrophotometry (Perkin Elmer, Model, Location, Williams et al., 1962)

Each cow's chromium excretion curve was analyzed using PROC NLIN following the method described by Pond et al. (1987, Table A.13 and Figure A.1). To calculate the intake of herbage, the following assumptions were made intake of supplement was the same for all cows within a paddock, digestibility of supplement was equivalent to its calculated TDN values based on the NRC (1989), and digestibility of forage was affected by amount of supplement intake, as determined by the equation of Moore and Kunkle (personal communication) The measure of forage IVOMD for each paddock was used to calculate forage intake by cows grazing that paddock. Fecal output (kg d$^{-1}$) should equal total intake (kg d$^{-1}$) multiplied by the indigestible fraction of a feed. However, fecal output observed based on the mordanted fiber method was not equal to the fecal output predicted based on forage and supplement digestibilities. Total dietary DM digestibility may be higher or lower than expected depending upon the effects of protein or grain supplements upon forage digestibility (Moore and Sollenberger, 1997, Dixon and Stockdale, 1999) Calculations of total dietary DM digestibility were adjusted for these associative effects by appropriate equations (Moore et al., 1997, Table A.14) Thus, a program created by Moore and Kunkle (personal communication) was employed to adjust the forage intake until the difference between fecal output observed and predicted differed by less than 0.01 kg $^{-1}$

Solid corrected milk (SCM) was calculated using a formula derived from Tyrell and Reid (1965) Solid corrected milk is calculated to place milk of varying composition on an equal basis with respect to energy content. Milk yield, milk fat yield, and protein yield are utilized in the formula

SCM 3.5% (solids corrected milk) = (12.82 x fat yield) + (7.13 x protein yield + 0.323) x milk yield

### Economic Analysis

Feed costs and income from milk were calculated for the two forage systems and the confined housing system. Calculation of feed costs included establishment and maintenance of pastures (Tables A.15 and A.16), costs of feedstuffs (Table A.17), costs of total mixed ration (TMR, Table A.18) for barn cows, concentrate supplement for grazing cows (Tables A.19 and A.20), one-shot concentrate supplement for grazing cows (Table A.21), total ration costs for three systems (Table A.22), costs of herbage (Table A.23) and amount and extent of utilization of concentrate supplements fed per cow (Table A.24).

### Statistical Analysis

The experimental design was a randomized complete block with four replications. Data were analyzed using SAS procedures for repeated measures (Littell et al., 1996, Littell et al., 1998, SAS, 1989).

The standard model for repeated measures experiment of animal and plant response variables was

$$y_{ij} = \mu + \alpha_i + d_i + \tau_j + (\alpha\tau)_{ij} + e_{ij}$$

where

$y_{ij}$ = the response at time j on treatment i,

$\mu$ = the overall mean,

$\alpha_i$ = fixed effect of treatment i,

$\tau_j$ = fixed effect of time j,

$(\alpha\tau)_{ij}$ = fixed interaction effect of treatment i with time j, and

$e_{ij}$ = random error at time j on treatment i.

Interactions between treatment and sampling period (time) were determined using contrast statements in PROC MIXED. Differences were considered to be significant at $P < 0.05$. Contrasts among systems were tested at each evaluation date for plant response variables (herbage mass, IVOMD, CP, NDF, and intake) and every 5 wk for animal response variables (milk yield, body weight, BCS, fat, protein and MUN concentration, and SCC). Polynomial equations until the 5th order were generated and tested, with the highest significant level included in the model. Economic variables: number of days open, and services per conception were analyzed using ANOVA models for completely randomized design in PROC MIXED (SAS, 1989).

## Results and Discussion

### Milk Yield and Liveweight

Cows in confined housing produced 20% more milk in the 276-d average period than cows on pasture systems (Figure 5.1 and Table 5.4). Tested at 5-wk intervals, there were differences among treatments ($P < 0.05$) on most dates. Between pasture systems

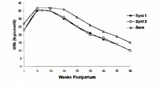

Figure 5.1. Milk yield (kg cow$^{-1}$ d$^{-1}$) on two pasture systems for dairy cows in comparison with a confined housing system. System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass.

Table 5.4. P-values and standard error (SE) for system comparisons of milk yield (kg cow$^{-1}$ d$^{-1}$) at Weeks 1 to 39 after parturition.

| System | Week | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 39 |
| Syst 1 vs Syst 2 | 0.792 | 0.340 | 0.567 | 0.905 | 0.997 | 0.981 | 0.877 | 0.909 | 0.185 |
| SE | 1.94 | 1.72 | 1.63 | 1.64 | 1.61 | 1.65 | 1.65 | 1.76 | 2.27 |
| Syst 1 vs Barn | 0.036 | 0.472 | 0.102 | 0.006 | 0.001 | 0.0005 | 0.0001 | 0.001 | 0.0001 |
| SE | 1.85 | 1.64 | 1.55 | 1.56 | 1.53 | 1.58 | 1.57 | 1.67 | 2.26 |
| Syst 2 vs Barn | 0.015 | 0.078 | 0.022 | 0.003 | 0.001 | 0.0004 | 0.0002 | 0.001 | 0.0762 |
| SE | 1.80 | 1.60 | 1.51 | 1.52 | 1.50 | 1.55 | 1.55 | 1.67 | 2.27 |

there were no differences ($P > 0.18$) in any experimental period. The seasonal average of milk production was 23.8, 24.2, and 28.9 kg cow$^{-1}$ d$^{-1}$, for systems 1, 2, and 3 (confinement), respectively. Kolver and Muller (1998) reported that during a 4-wk experimental period, cows consuming an all pasture diet produced 33% less ($P < 0.01$) milk than cows fed a TMR (29.6 vs. 44.1 kg cow$^{-1}$ d$^{-1}$), and had a milk protein concentration that was 0.19 percentage units lower. Fike et al. (1997a,b) reported large decreases (10 to 15 kg d$^{-1}$) in milk production for cows moved from a confined housing system to bermudagrass or rhizoma peanut (*Arachis glabrata* Benth.) pastures in Florida in mid-summer. In the present experiment, when systems were contrasted every 5 wk, no differences ($P > 0.05$) among treatments were detected in concentration of milk fat, protein, or urea N (Table 5.5). However, somatic cell count (SCC) were different ($P < 0.05$) from Week 5 to 14 postpartum, with System 3 (confinement) cows presenting higher SCC than pasture cows (Table 5.5).

Grazing cows lost more weight than did confined cows (Figure 5.2 and Table 5.6), especially cows in System 1 (rye-ryegrass-clovers/pearl millet). These cows maintained their liveweight during the summer, while cows in System 2 (rye-ryegrass-bermudagrass) increased in liveweight. However, differences in liveweight between grazing systems approached significance only in the last 10-wk of the experiment. Weight of confined and System 1 cows were different ($P < 0.10$) beginning between Weeks 5 and 10 through to end of experiment, while there were only trends ($P < 0.20$) during most of this time period toward higher weights in barn cows than System 2 cows.

During the total experiment, grazing cows lost an average of 0.19 (System 2) and 0.26 kg d$^{-1}$ (System 1), while confined cows gained 0.13 kg d$^{-1}$. Confined cows rapidly

Table 5.5 Seasonal average of milk yield (4% FCM), solid corrected milk (SCM), fat and protein percentage, milk urea nitrogen (MUN) and milk somatic cell count (SCC) on pasture systems for grazing compared to confined housing.

| System† | Raw milk | FCM‡ | SCM§ | Fat | Protein | MUN | SCC |
|---|---|---|---|---|---|---|---|
| | ---------- kg cow$^{-1}$ d$^{-1}$ | | ---------- | % | % | mg % | x 1,000 |
| 1 | 25.2b | 23.8b¶ | 25.4b | 3.60a | 2.96a | 17.1a | 223a |
| 2 | 25.0b | 24.2b | 24.7b | 3.70a | 2.95a | 15.6a | 364a |
| Barn | 29.8a | 28.9a | 29.3a | 3.69a | 2.90a | 16.5a | 654b |

† System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass
‡ 4% FCM (fat corrected milk) = 0.40 x milk yield (kg day$^{-1}$ ) + 15 x fat yield (kg day$^{-1}$)
§ SCM (3.5%) = 12.82 x fat yield + 7.13 x protein yield + 0.323 x milk yield
¶ Values within a column followed by the same letter are not different (P > 0.05) for any 5-wk interval contrast. For SCC the comparisons are from Week 5 to 14

increased in body weight (BW) and body condition score (BCS) during the last 10 wk of trial, while grazing cows tended to do the same in the last 3 to 5 wk (Figure 5.3 and Table 5.7)

Considering that the net energy for lactation (NEL) equivalent to a weight loss of 1 kg of body tissue is 4.92 Mcal (NRC, 1989), changes in body weight were equivalent to 1.74 and 1.26 kg of milk cow$^{-1}$ d$^{-1}$ for Systems 1 and 2, respectively. Barn cows gained weight with an NEL equivalent of 0.9 kg of milk cow$^{-1}$ d$^{-1}$ (NEL = 5.12 Mcal kg$^{-1}$ gain, NRC, 1989). Therefore, barn cows had caloric value of liveweight changes equivalent to 2.2 and 2.6 kg milk (FCM = 4%) greater than Systems 1 and 2, respectively

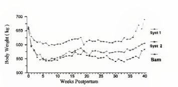

Figure 5.2 Body weight (kg cow$^{-1}$) for dairy cows on two pasture systems compared with a confined housing system. System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass

Table 5.6 P-values and standard error (SE) for system comparisons of body weight (kg cow$^{-1}$) at Weeks 0 to 40 after parturition

| | Week | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| System | 0 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 39 | 40 |
| Syst 1 vs 2 | 0.834 | 0.767 | 0.677 | 0.704 | 0.696 | 0.578 | 0.404 | 0.260 | 0.198 | 0.265 |
| SE | 23.2 | 22.6 | 22.5 | 22.2 | 22.3 | 22.2 | 22.3 | 22.3 | 22.6 | 26.0 |
| Syst 1 vs Barn | 0.980 | 0.404 | 0.019 | 0.030 | 0.077 | 0.058 | 0.022 | 0.013 | 0.015 | 0.003 |
| SE | 22.1 | 21.5 | 21.4 | 21.2 | 21.2 | 21.2 | 21.1 | 21.2 | 21.5 | 24.8 |
| Syst 2 vs Barn | 0.801 | 0.592 | 0.052 | 0.070 | 0.164 | 0.179 | 0.149 | 0.182 | 0.265 | 0.074 |
| SE | 21.5 | 21.0 | 20.9 | 20.6 | 20.7 | 20.6 | 20.7 | 20.7 | 21.1 | 24.6 |

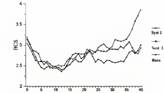

Figure 5.3 Body condition score (BCS) on two pasture systems for dairy cows compared with a confined housing system. System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass

Table 5.7 P-values and standard error (SE) for system comparisons of body condition score at Weeks 0 to 40 after parturition.

| System | Week 1 | 5 | 10 | 15 | 20 | 25 | 30 | 35 | 39 | 40 |
|---|---|---|---|---|---|---|---|---|---|---|
| Syst 1 vs. 2 | 0.648 | 0.556 | 0.503 | 0.671 | 0.692 | 0.417 | 0.124 | 0.047 | 0.190 | 0.234 |
| SE | 0.18 | 0.16 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.22 |
| Syst 1 vs Barn | 0.700 | 0.856 | 0.688 | 0.558 | 0.520 | 0.362 | 0.120 | 0.015 | 0.001 | 0.010 |
| SE | 0.17 | 0.16 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.20 |
| Syst 2 vs Barn | 0.374 | 0.408 | 0.749 | 0.891 | 0.821 | 0.961 | 0.932 | 0.748 | 0.054 | 0.0001 |
| SE | 0.17 | 0.15 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.14 | 0.21 |

Lack of recovery in BW and BCS (Figure 5.3, Tables 5.7 and 5.8) can have negative implications on subsequent reproduction and milk yield of the next (NRC, 1989). In the current study there appeared to be effects of condition and weight loss because cows grazing pasture had more days open and more services per conception than confined cows (Table 5.8).

## Herbage Mass

Pregraze and postgraze herbage mass in winter/spring averaged 2350 ± 330 and 910 ± 190 kg of DM $ha^{-1}$, respectively. Pregraze and postgraze herbage mass in summer averaged 3580 ± 830 and 2400 ± 630 kg DM $ha^{-1}$. There were no differences in herbage mass between pasture systems during winter and through 23 July in summer (Figure 5.4, Table 5.9). This situation changed during late summer when pearl millet decreased its growth rate. From 12 August throughout September, Tifton 85 bermudagrass (System 2) herbage mass was greater than that of pearl millet.

## Botanical Composition

During winter, the average contribution of ryegrass was 47% in pastures with clovers (System 1) and 59% in pastures without legumes (System 2, Table 5.10). The ryegrass contribution increased and rye decreased as the season progressed. Rye contributed with approximately one-third of total DM over the growing season. Crimson and red clovers made the greatest contribution late in the growth season, 20 to 25% of total DM in April/May (more than 500 kg of DM $ha^{-1}$). The weed component contributed little DM, only during late May when the warm-season species began growth was it above 10%.

Table 5.8 Liveweight (LW), body condition score (BCS), days open, and services per conception on pasture systems for grazing

| System† | Initial LW | Final LW | Daily LW changes | Initial BCS | Final BCS | BCS change | Days open | Services per conception |
|---|---|---|---|---|---|---|---|---|
| | –kg– | –kg– | -kg cow$^{-1}$- | | | | | |
| 1 | 656a‡ | 583b | −0.26 | 3.13a | 2.88b | −0.25 | 183b | 3.3b |
| 2 | 660a | 606b | −0.19 | 3.19a | 3.00b | −0.19 | 172b | 3.3b |
| Barn | 655a | 690a | +0.13 | 3.04a | 3.83a | +0.79 | 136a | 2.1a |
| SE | 22 | 22 | | 0.15 | 0.15 | | 67 | 1.6 |

† System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass
‡ Values within a column followed by the same letter are not different ($P > 0.1$) by LSD

### Nutritive Value

Forage digestibility (IVOMD) was not different between systems at any of the 12 sampling dates (Figure 5.5 and Tables 5.11 and 5.12), and it decreased during both seasons. Except for the last spring sampling date, digestibility of winter pastures was between 700 and 800 g kg$^{-1}$ OM. There were trends ($P < 0.098$ to $0.228$) toward higher IVOMD on System 1 pearl millet pastures than bermudagrass during late July through September. Throughout summer, IVOMD on both systems ranged from more than 600 to just less than 750 g kg$^{-1}$.

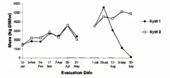

Figure 5.4 Pregraze herbage mass (kg DM ha$^{-1}$) on two pasture systems for dairy cows System 1 = Rye-ryegrass-clovers/pearl millet and System 2 = Rye-ryegrass/bermudagrass.

Table 5.9 P-values and standard error (SE) for system comparisons of pregraze herbage mass (kg DM ha$^{-1}$) for January to September of 1998

| Date | 12 Jan | 3 Feb | 24 Feb | 17 Mar | 7 Apr | 28 Apr | 21 May | 1 July | 23 July | 12 Aug | 3 Sep | 25 Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| P-value | 0.90 | 0.35 | 0.26 | 0.53 | 0.86 | 0.28 | 0.13 | 0.33 | 0.61 | 0.001 | 0.0001 | 0.0001 |
| SE | 601 | 365 | 349 | 360 | 338 | 306 | 306 | 338 | 360 | 349 | 365 | 601 |

Table 5.10 Botanical composition of winter pastures.

| Date | System 1 | | | | System 2 | | |
|---|---|---|---|---|---|---|---|
| | Rye | Rg† | Clovers | Weeds | Rye | Rg | Weeds |
| | % | | | | | | |
| 12 Jan. | 30 | 55 | 12 | 3 | 42 | 58 | 0.4 |
| 3 Feb. | 52 | 36 | 6 | 7 | 47 | 48 | 5 |
| 14 Feb. | 48 | 46 | 6 | 0.6 | 53 | 47 | 0 |
| 17 Mar. | 38 | 45 | 18 | 0 | 40 | 60 | 0 |
| 7 Apr | 37 | 55 | 8 | 0 | 33 | 58 | 9 |
| 28 Apr | 9 | 65 | 26 | 0 | 11 | 89 | 0.6 |
| 21 May | 0 | 30 | 21 | 49 | 0 | 53 | 47 |
| avg | 30 | 47 | 14 | 9 | 32 | 59 | 9 |

†Rg = ryegrass

The CP concentration was not different ($P > 0.40$) between systems during winter (Figure 5.6, Tables 5.12 and 5.13). There were differences during August and September when pearl millet CP was greater than that of bermudagrass.

The NDF concentration was not different between systems ($P > 0.15$) during most the winter season (Figure 5.7, Table 5.12 and 5.14). During winter NDF of rye-ryegrass-clover herbage averaged 466 g kg$^{-1}$ DM while rye-ryegrass herbage averaged 481 g kg$^{-1}$ DM ($P < 0.257$). However, during summer, pearl millet on System 1 had lower NDF, an average of 586 g kg$^{-1}$ DM, than did bermudagrass on System 2 (726 g kg$^{-1}$ DM).

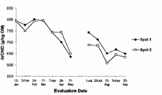

Figure 5.5. In vitro organic matter digestibility (IVOMD; g kg$^{-1}$ OM) of handplucked samples on two pasture systems for dairy cows. System 1 = Rye-ryegrass-clovers/pearl millet and System 2 = Rye-ryegrass/bermudagrass.

Table 5.11 P-values and standard error (SE) for system comparisons of herbage IVOMD (g kg$^{-1}$ OM) from January to September of 1998.

| Date | 12 Jan | 3 Feb | 24 Feb | 17 Mar | 7 Apr | 28 Apr | 21 May | 1 Jul | 23 Jul | 12 Aug | 3 Sep | 25 Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| P value | 0.70 | 0.73 | 0.78 | 0.83 | 0.83 | 0.77 | 0.63 | 0.44 | 0.23 | 0.11 | 0.10 | 0.13 |
| SE | 22 | 16 | 12 | 12 | 12 | 13 | 13 | 12 | 12 | 12 | 16 | 22 |

Table 5.12 Average forage nutritive value across evaluation dates within seasons of handplucked samples on pasture systems for grazing

| Response Variable | Period | System 1† | System 2 | SE | P-value |
|---|---|---|---|---|---|
| | | ------------------------ $g\ kg^{-1}$ ------------------------ | | | |
| Forage IVOMD | Year | 721 | 711 | 14.5 | 0.52 |
| | Winter | 749 | 753 | 14.3 | 0.75 |
| | Summer | 681 | 652 | 14.8 | 0.21 |
| Forage CP | Year | 238 | 223 | 14.0 | 0.46 |
| | Winter | 248 | 247 | 13.8 | 0.69 |
| | Summer | 223 | 190 | 14.4 | 0.14 |
| Forage NDF | Year | 516 | 583 | 21.1 | 0.15 |
| | Winter | 466 | 481 | 20.8 | 0.26 |
| | Summer | 586 | 726 | 21.6 | 0.0002 |

† System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass

Forage and Total Intake

Once in winter and once in summer, dry matter intake was determined using chromium marker techniques. Forage or total intake was not different between forage systems in either season (Table 5.15), but they were between seasons. Cows consumed more herbage and total forage during winter than during summer. Total intake for the grazing systems was 21.8 kg DM cow$^{-1}$ d$^{-1}$ whereas it was 23.6 kg of DM cow$^{-1}$ d$^{-1}$ for barn cows. Forage intake was 13.4 and 10.6 kg DM cow$^{-1}$ d$^{-1}$, for winter and summer pastures, respectively. This amount of herbage consumed represented an average of about 55% of total intake. These results are similar to those reported by others authors. Muller et al. (1995) reported daily consumption of 22.2 kg cow$^{-1}$ of which 14.5 kg DM came

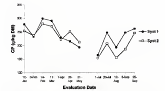

Figure 5.6 Crude protein (CP, g kg$^{-1}$ DM) of handplucked samples on two pasture systems for dairy cows. System 1 = Rye-ryegrass-clovers/pearl millet and System 2 = Rye-ryegrass /bermudagrass

Table 5.13. P-values and standard error (SE) for system comparisons of herbage CP (g kg$^{-1}$ DM) from January to September of 1998

| Date | 12 Jan | 3 Feb | 24 Feb | 17 Mar | 7 Apr | 28 Apr | 21 May | 1 Jul | 23 Jul | 12 Aug | 3 Sep | 25 Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| P-value | 0.40 | 0.47 | 0.62 | 0.82 | 0.92 | 0.88 | 0.72 | 0.45 | 0.17 | 0.05 | 0.03 | 0.03 |
| SE | 21.5 | 15.3 | 12.0 | 11.3 | 12.0 | 12.6 | 12.7 | 12.0 | 11.3 | 11.9 | 15.3 | 21.5 |

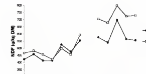

Figure 5 7 Neutral detergent fiber (NDF, g kg$^{-1}$ DM) of handplucked samples on two pasture systems for dairy cows. System 1 = rye-ryegrass-clovers/pearl millet and system 2 = rye-ryegrass/bermudagrass

Table 5 14 P-values and standard error (SE) for system comparisons of herbage NDF (g kg$^{-1}$ DM) from January to September of 1998

| Date | 12 Jan | 3 Feb | 24 Feb | 17 Mar | 7 Apr | 28 Apr | 21 May | 1 Jul | 23 Jul | 12 Aug | 3 Sep | 25 Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| P-value | 0.286 | 0.323 | 0.866 | 0.576 | 0.287 | 0.133 | 0.025 | 0.0008 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |
| SE | 32.2 | 22.9 | 17.9 | 16.9 | 17.9 | 18.8 | 18.8 | 17.9 | 16.9 | 17.9 | 22.9 | 32.2 |

Table 5.15 Intake of cows on pasture systems for grazing.

| Response Variable | Period | System 1† | System 2 | SE | P-value |
|---|---|---|---|---|---|
| | | kg DM cow$^{-1}$ d$^{-1}$ | | | |
| Forage Intake (Chromium) | Year | 12.1 | 11.9 | 2.8 | 0.73 |
| | Winter (April) | 13.3 | 13.5 | 2.8 | 0.87 |
| | Summer (July) | 10.9 | 10.3 | 2.8 | 0.59 |
| Forage Disappeared‡ | Year | 10.8 | 11.9 | 2.1 | 0.18 |
| | Winter | 13.1 | 14.7 | 2.0 | 0.25 |
| | Summer | 7.5 | 8.0 | 2.1 | 0.09 |
| Total Intake (Chromium) | Year | 21.9 | 21.8 | 3.1 | 0.91 |
| | Winter (April) | 24.7 | 24.8 | 2.9 | 0.95 |
| | Summer (July) | 19.1 | 18.9 | 3.1 | 0.86 |

† System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass
‡ Sward difference method

from grass alfalfa pasture. Holden et al. (1994b) reported daily forage intake on a mixture of perennial cold season grasses ranged from 11.6 to 25.6 kg DM and was lowest in the summer, while the total DMI increased from 21.3 kg in early spring to 22.4 kg in late spring, and after decreased as lactation progressed. In the current experiment, the average herbage disappearance calculated using the sward difference method was similar to that measured using the chromium marker (11.3 kg of DM cow$^{-1}$ d$^{-1}$).

Average pregraze and postgraze herbage masses were not different between systems within a season (Table 5.16). System 2 (bermudagrass) tended to have greater herbage mass during the summer season ($P < 0.20$) and it also tended to have greater

Table 5.16 Average pregraze and postgraze herbage mass and herbage disappeared during grazing for two pasture systems for dairy cows.

| Season | | **Pregraze herbage** | | |
|---|---|---|---|---|
| | Syst 1† | Syst 2 | SE | P-value |
| | | kg ha$^{-1}$ | | |
| Winter | 2330 | 2370 | 375 | 0.474 |
| Summer | 2670 | 4490 | 402 | 0.187 |
| Year | 2470 | 3250 | 386 | 0.354 |
| Season | | **Postgraze herbage** | | |
| | Syst 1† | Syst 2 | SE | P-value |
| | | kg ha$^{-1}$ | | |
| Winter | 1050 | 770 | 328 | 0.326 |
| Summer | 1550 | 3240 | 349 | 0.149 |
| Year | 1260 | 1800 | 337 | 0.252 |
| Season | | **Disappeared herbage** | | |
| | Syst 1† | Syst 2 | SE | P-value |
| | | kg ha$^{-1}$ | | |
| Winter | 1280 | 1600 | 821 | 0.131 |
| Summer | 1120 | 1240 | 248 | 0.080 |
| Year | 1210 | 1450 | 582 | 0.109 |

† System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass

forage disappearance per hectare during both seasons and for the yearly average ($P < 0.13$). The yearly average of grazing efficiency (forage disappeared/pregraze herbage mass) was 47%. There was greater grazing efficiency for winter pastures, about 62%, while for summer pastures the range was from 28 to 42%.

When using the sward difference method to estimate forage dry matter intake (DMI), cows on the two forage systems differed on several sampling dates (Figure 5.8, Table 5.17). From late February to March, System 2 (without legumes) had greater estimated forage intake than System 1 (with clover). Differences probably occurred because of forage composition, maturity, and structure of forage components. In that time, a greater proportion of the forage in System 2 was ryegrass (55%) while in System 1 the most abundant component was rye (41%). During April, no differences between existed systems. However, in the last winter evaluation the trend was reversed and System 1 tended ($P < 0.17$) to have greater intake, probably due to contribution of clovers (20-25%). During the summer period, cows on System 1 (pearl millet) had greater herbage DM intake in July evaluations (Figure 5.8, Table 17), but there were no differences ($P < 0.15$) between systems in August and early-September evaluations. During late-September cows on System 2 (bermudagrass) had greater herbage DM intake, probably due to reduced pearl millet allowance at that time. Barn cows consumed about 8% more DM than pasture systems, (23.6 vs. 21.8 kg $d^{-1}$). Based on BW, the seasonal average was 3.92, 3.80, and 3.91% of BW for System 1, 2, and 3 (confinement), respectively, DMI at more than the 3.5% of BW as estimated by NRC (1989) is required for maintenance and normal weight gain during mid-and late lactation of a 600-kg cow, with daily milk production of 30 kg. Cow daily intake of DM was 12, 9, and 12% greater than estimated by NRC (1989) for Systems 1, 2, and 3, respectively.

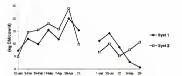

Figure 5.8. Estimated forage intake (kg DM cow$^{-1}$ d$^{-1}$) based on the sward difference method on two pasture systems for dairy cows. System 1= Rye-ryegrass-clovers/pearl millet and System 2 = Rye-ryegrass/bermudagrass

Table 5.17. P-values and standard error (SE) for system comparisons of estimated forage intake (kg cow$^{-1}$ d$^{-1}$ DM) from January to September of 1998

| Date | 12 Jan | 3 Feb | 24 Feb | 17 Mar | 7 Apr | 28 Apr | 21 May | 1 Jul | 23 Jul | 12 Aug | 3 Sep | 25 Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Time | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| Syst 1 vs 2 | 0.45 | 0.16 | 0.01 | 0.02 | 0.11 | 0.83 | 0.17 | 0.03 | 0.023 | 0.37 | 0.23 | 0.001 |
| SE | 3.2 | 1.9 | 1.9 | 1.9 | 1.8 | 1.6 | 1.6 | 1.8 | 1.9 | 1.9 | 1.9 | 3.2 |

## Economic Analysis

Total milk production cost is much more complex than feed cost alone. However, feed cost is the most important component of production costs in dairy operations. This section assesses the feed cost relative to milk income of the two pasture system treatments compared with the conventional housing system.

Pasture cost was about $\$300\ \text{ha}^{-1}$ for both winter and summer pastures (Table A.16). There was a 3% greater cost ($\$9.74\ \text{ha}^{-1}$) for the winter component of System 1 due to the cost of clover seed that was not totally compensated for by additional N fertilization on System 2 (rye-ryegrass-without clovers). Summer pastures of System 1 (pearl millet) had a 15% greater ($\$43.89\ \text{ha}^{-1}$) cost than those of System 2 (bermudagrass).

Total mixed ration for barn cows and concentrate supplement costs for grazing cows are summarized in Tables A.17 to A.21. Total mixed ration cost was $\$0.093\ \text{kg}^{-1}$ as-fed, i.e., $\$4.20\ \text{cow}^{-1}\ \text{d}^{-1}$ (intake of $45.13\ \text{kg cow}^{-1}\ \text{d}^{-1}$). Average supplement costs for grazing cows were \$0.151 and $\$0.153\ \text{kg}^{-1}$ as-fed, or \$1.94 and $\$1.83\ \text{cow}^{-1}\ \text{d}^{-1}$ for Systems 1 and 2, respectively (Table 5.18). The higher cost of System 1 was basically due to summer one-shot supplement fed during the last month of trial due to a shortage of pearl millet forage.

In addition to concentrate supplement and pasture cost, the cows of one replicate of both systems received $9\ \text{kg cow}^{-1}\ \text{d}^{-1}$ of corn silage from 19 February to 17 March due to poor regrowth of rye. From 28 April to 18 May, the cows of one replicate of System 2 (bermudagrass) were fed $11\ \text{kg silage cow}^{-1}\ \text{d}^{-1}$ (as-fed basis). Corn silage costs were \$0.009 and $\$0.018\ \text{cow}^{-1}\ \text{d}^{-1}$ for Systems 1 and 2, respectively (Table 5.18 and Table A.17).

Table 5.18 Feed cost and milk income of two pasture systems for grazing and a confined housing system.

| System† | Conc. or TMR as-fed | Conc. Suppl. or TMR | Pasture Cost | Milk Income | Difference |
|---|---|---|---|---|---|
| | kg $cow^{-1} d^{-1}$ | \$ $cow^{-1} d^{-1}$ | \$ $cow^{-1} d^{-1}$ | \$ $cow^{-1} d^{-1}$ | \$ $cow^{-1} d^{-1}$ |
| 1‡ | 12.9b§ | 1.94b | 0.35a | 7.85b | 5.56a |
| 2 | 12.0b | 1.83c | 0.30b | 7.99b | 5.84a |
| Barn | 45.1a | 4.20a | - | 9.52a | 5.32a |
| SE | 0.33 | 0.05 | 0.02 | 0.37 | 0.36 |

† Syst 1 = rye-ryegrass-clovers/pearl millet. Syst 2 = rye-ryegrass/bermudagrass

‡ Corn silage cost was \$0.009 and \$0.018 $cow^{-1} d^{-1}$ for Syst 1 and 2, respectively

§ Means in the same column followed by the same letter are not different ($P > 0.10$) by LSD

Even though milk income of barn cows was greater than grazing cows, milk income above feed cost was less (\$0.24 $cow^{-1} d^{-1}$) than those for System 1 (pearl millet), and \$0.52 $cow^{-1} d^{-1}$ less than on System 2 (bermudagrass, Table 5.18). System 2 presented income above feed cost of \$5,480 $ha^{-1}$ compared to \$4,790 $ha^{-1}$ for System 1 (Table 5.19), but these values were not different statistically.

As the milk yield was the same, trends toward cost differences were due to lower cost of bermudagrass pasture, the longer grazing period on bermudagrass than for pearl millet, and the cost of concentrate supplement during the last month of trial due to a shortage of pearl millet.

Table 5.19 Milk income minus feed costs (concentrate supplement and pasture) for two pasture systems

| System† | Milk Production | Milk Prod. | Milk Income | Feed Cost | Difference Milk - Feed |
|---|---|---|---|---|---|
| | kg cow$^{-1}$ d$^{-1}$ | kg ha$^{-1}$ | $\$$ ha$^{-1}$ | $\$$ ha$^{-1}$ | $\$$ ha$^{-1}$ |
| 1 | 23.8a | 21,350a | 7,050a | 2,260a | 4,790a |
| 2 | 24.2a | 23,209a | 7,660a | 2,180a | 5,480a |
| SE | 1.1 | 1,833 | 605 | 202 | 445 |

† System 1 = rye-ryegrass-clovers/pearl millet and System 2 = rye-ryegrass/bermudagrass

‡ Means in the same column followed by the same letter are not different ($P > 0.10$) by LSD

## Summary and Conclusions

To better assess the potential of pasture-based dairy systems in Florida, a 276-d experiment was conducted at UF-Dairy Research Unit (DRU) in Hague, FL. The objectives were: a) to compare milk production and composition from pasture-based systems for lactating dairy cows with those of a conventional confinement housing system, and b) to compare feeding costs per unit of milk produced for the two pasture systems and a conventional confinement housing system. A total of 40 multiparous Holstein cows were assigned to treatments at calving. Twelve cows were assigned to each of two forage systems with three cows on each of four replicates per system and 16 cows in the barn. System 1 was a rye-ryegrass-clovers (crimson and red) mixture during winter-spring and pearl millet during summer. System 2 was a rye-ryegrass mixture during winter-spring and bermudagrass during summer. Both were compared with a conventional confinement housing (System 3). The grazing period was from early January to early

October, 1998. A 1-d grazing period was used with a 28-d rest periods during winter-spring, and a 21-d rest periods during summer. Supplement was fed at a rate of 1 kg (as-fed) for each 2.5 kg milk produced during winter and 1.2 during the summer.

Cows in confined housing produced an average of 20% more milk than cows on the pasture systems. Milk yield between grazing systems did not differ as did milk fat, milk protein, and milk urea nitrogen concentrations. Grazing cows lost 0.19 (System 2) and 0.26 kg d$^{-1}$ (System 1), while confined cows gained 0.13 kg d$^{-1}$ of body weight (BW). Confined cows rapidly increased BW and BCS during the last 10 wk of the trial while grazing cows tended to do that in the last 3 to 5 wk. Grazing cows had more days open and more services per conception than confined cows.

There were no differences between forage systems in either season for forage and total DM intake. Barn cows consumed about 8% more than grazing cows. Forage intake from pasture was approximately 55% of total intake.

There were no differences in herbage mass between pasture systems during winter through early August, but after that bermudagrass had greater herbage mass than pearl millet. Both rye and ryegrass contributed significantly to total herbage mass during winter, after which ryegrass contribution increased and rye decreased as spring progressed. Clovers made the greatest contribution during April and May. Herbage digestibility, CP, and NDF concentration were similar between grazing systems during winter and spring. The NDF concentration of bermudagrass herbage was greater than that of pearl millet. Pearl millet herbage CP was greater than bermudagrass during August and September. There were trends toward greater IVOMD on pearl millet than bermudagrass during summer.

Cool-season annual forages planted in October provided high nutritive value forage from early January to May (5 mo), a time when perennial warm-season grasses have low growth and nutritive value. Late May through June is a transition period between annual cool-season and perennial warm-season pasture in north Florida, and other alternatives, such as feeding conserved forage or early planting of annual warm-season pastures (pearl millet and sorghum species) may be necessary. Conserved forage or late planting of warm-season annuals also may be used to fill the gap between warm-season and cool-season pastures, from October to December.

Pearl millet had low growth after late August, however, by staggering planting dates it may have potential to extend the grazing season from May to November and provide forage of greater nutritive value than most perennial warm-season grasses. However, the main disadvantages of forage systems based on annual species are related to the higher risk due to seasonal establishment and also due to higher costs relative to perennial pastures.

Although confined cows produced 20% more milk than grazing cows, the feed cost of grazing cows was reduced to about one half that of confined cows. Milk income minus feeding costs was $5.56, $5.84, and $5.32 cow$^{-1}$ d$^{-1}$ for System 1 (pearl millet), System 2 (bermudagrass), and Sytem 3 (confinement), respectively. Data from this experiment show no animal production or economic benefit of using pearl millet instead of bermudagrass. This is likely due to the shorter season of production and greater cost of millet versus bermudagrass systems, and to the relatively high amount of concentrate fed to grazing animals, which likely reduced the impact of higher nutritive value of pearl millet. These date support the idea that reduction in feed costs may be included among several reasons for greater interest in pasture-based systems for dairy cows in the north central Florida region.

# CHAPTER 6
# GENERAL CONCLUSIONS

The purpose of this chapter is to summarize findings and practical implications of three experiments described in Chapters 3 through 5. They were planned to test forage systems for year-round grazing by lactating dairy cows, because most of the research done with pasture systems has been short term in nature and full lactation studies are needed to better assess the potential of pasture-based systems. Two were preliminary to refine agronomic management information for year-round pasture systems. The preliminary experiments were conducted at Beef Research Unit (BRU), north of Gainesville, from May 1996 to May 1998, and the primary trial was conducted at the Dairy Research Unit (DRU), at Hague, from January to October 1998.

In the first trial described in Chapter 3, three cultivars of pearl millet and two of sorghum-sudangrass were planted at four (1996) and six (1997) dates separated by 3-wk intervals. Planting dates started on 10 May 1996 and 20 March 1997. The objectives were to quantify total-season DM yield, seasonal distribution, and nutritive value. The plants were clipped when 50- to 60-cm tall to a 10-cm stubble, approximately every 2 to 4 wk. The plots received 40 kg N ha$^{-1}$ after the first four harvests of each planting date.

In both years, total yield decreased linearly as planting date was delayed, at a rate of about 30 kg DM ha$^{-1}$ d$^{-1}$. An exception was Tifleaf 2 millet in 1997, it tended to maintain forage yield from March to June plantings. Yield among cultivars did not differ consistently in either year, however SX 15 sorghum had greater yield than Hygrazer in late plantings (late May through July)   Although the greatest herbage yield occurred in summer, forage distribution may be improved and the autumn deficit reduced by planting pearl millet and sorghum-sudangrass genotypes at two or more 3-wk interval dates and utilizing intensive management including frequent harvests   Leaf percentage for most cultivars decreased linearly as planting date was delayed and Tifleaf 2 had or tended to have the greatest leaf percentage independent of planting date

Nutritive value was high and there were no differences in total herbage IVOMD and CP concentration among genotypes at most harvests   Total herbage and leaf and the lowest CP concentration at the earliest planting date   The CP concentration ranged between 127 to 178, 144 to 199, and 75 to 148 g kg$^{-1}$ DM for total herbage, leaf, and culm fractions, respectively, while IVOMD ranged between 660 to 695, 675 to 712, and 628 to 690 g kg$^{-1}$ OM, respectively

The main practical implication of these findings is that forage distribution and forage nutritive value may be improved and autumn deficit reduced by planting pearl millet and sorghum-sudangrass genotypes using multiple planting dates and utilizing frequent harvests

The second trial, described in Chapter 4, included six cool-season forage mixtures composed of small grains (rye and oat), ryegrass, and crimson or red clovers   Mixtures were tested at four planting dates at 4-wk intervals from 19 Sept  to 11 Dec  1996 and from 2 Oct  to 23 Dec  1997 to determine total forage yield, seasonal forage distribution, and nutritive value   The treatments were R-O (rye-oat), R-O-Crim (crimson clover), R-O-Red (red clover), and each of these treatments with Italian ryegrass (Rg)   Plots were sampled when forage was 25- to 40-cm tall using a sickle-bar mower to cut to a 7- to 10-cm stubble height.

The R-O-Rg mixture was highest yielding in both years. All mixtures had higher yields in 1996 than in 1997 due to excessive winter and spring rains (210% above the 257-mm average from November 1997 to February 1998). In the wet year, yields of mixtures with ryegrass decreased less than those without ryegrass. October and November planting dates resulted in greater DM yield than earlier or later planting for most mixtures, but the R-O mixture tended to have greatest yield when planted in September to early October. Relative to botanical composition, small grains and crimson clover made up a lesser percentage of the total DM in the wetter year, while ryegrass and red clover percentages were greater in the wetter year. Time of first harvest was delayed as planting date was delayed each year, and only when planting occurred in September was there a harvest during the late fall (before 21 December) growth period. The R-O mixture produced forage through no later than early spring (before 8 May), while mixtures including ryegrass and clover tended to produce significant forage after 8 May. The clovers were primarily responsible for extending the growing season, while the main contribution of ryegrass was to increase forage production in spring. Crimson clover extended production to mid-May and red clover throughout May.

Herbage nutritive value was high, with IVOMD averaging more than 700 g kg$^{-1}$ OM across treatments, and although IVOMD decreased from late winter to late spring harvests it still remained at about 600 g kg$^{-1}$ OM. Mixtures including ryegrass had the highest overall IVOMD for all planting dates in both years. The mixtures maintained high CP concentration (> 160 g kg$^{-1}$ DM) during fall and winter, and despite declining later, CP was maintained at about 130 g $kg^{-1}$ during late spring due to ryegrass and clover components. Mixtures of cool-season annual grasses with clovers may be an important alternative to develop economical forage systems for year-round grazing by dairy cows in north central Florida, and forage distribution and herbage nutritive value may be improved by growing these species in systems based on warm-season perennial grasses.

The main practical implications of these findings are that combinations of planting dates and especially choosing appropriate mixtures of small grains, ryegrass, and clovers, along with appropriate selection of cultivars, may allow production of forage for grazing from late-December or early-January through May (4 to 5 mo), a period in which perennial warm-season grasses lack both the production and nutritive value necessary for lactating dairy cows.

The third and primary experiment used extended lactation studies to better assess the potential of pasture-based systems, specifically the idea that these systems may reduce cost of milk production per unit of feed cost relative to conventional confinement housing. The two main objectives were to compare milk production and composition from pasture-based systems for lactating dairy cows with those of a conventional confinement housing system, and to compare feeding costs per unit of milk produced for the two pasture systems and a conventional confinement housing system.

The 276-d grazing period experiment used a total of 40 multiparous Holstein cows starting at calving in January and ending in October 1998. Three cows were assigned to each of four replications of two year-round pasture systems, with grazing periods of 1 d and resting periods of 21 to 28 d. System 1 was based on a rye-ryegrass-crimson and red clovers mixture during winter and pearl millet during summer. System 2 was based on a rye-ryegrass mixture during winter and bermudagrass during summer  Both were compared with System 3, conventional confinement housing.  Pasture cows received supplement at a rate of 1 kg per 2 5 kg of milk produced during winter and 1 kg per 2 kg of milk in summer  Sixteen cows were assigned to the confinement housing treatment, fed a total mixed ration, and cooled by fans and misters

Cows in confinement produced 20% more milk (29 vs. 24 kg milk cow$^{-1}$ d$^{-1}$) than those on pasture systems, there were no differences between Systems 1 and 2.  There were no differences among the three systems in concentration of milk fat, protein, and urea nitrogen.  However, somatic cell count was higher for the confined system than pasture systems.  Grazing cows lost more weight than confined, especially cows grazing pearl millet that only maintained body weight during most of the summer while cows on other treatments gained weight.  Pasture cows had greater number of days open and services per conception than confined cows

Pregraze herbage mass averaged  2300 and 3600 kg DM ha$^{-1}$ for winter and summer pastures, respectively, however, during August through September pearl millet pregraze herbage was reduced to about 1000 kg ha$^{-1}$  During winter, ryegrass contributed 40 to 60% of total forage, while clovers, with 20 to 25% of herbage, were important in April to May

Herbage IVOMD was similar between forage systems and decreased linearly from 790 to 640, and from 720 to 630 g kg$^{-1}$OM, as the winter and summer seasons progressed, respectively  The NDF and CP concentrations were not different during winter, but during the summer, System 2 presented higher NDF and lower CP, especially during

August through September. During these months bermudagrasss forage allowances were about four times greater than those of pearl millet pastures.

The total year average intake for both pasture systems was 21.8 kg DM $cow^{-1}$ $d^{-1}$, with forage intake of 12.0 kg $d^{-1}$. Both total and forage intake were higher during winter than the summer period. Confined cows consumed 8% more total DM than pasture systems cows.

Economic analysis suggests that System 2 had the lowest feed cost per unit of milk produced and that pasture systems based on perennial forages may be more likely to succeed than those based on annuals, even annuals of high quality.

# APPENDIX

Table A.1. Planting date by growth period interaction for rye-oat DM yield for cool-season forage mixtures planted at four planting dates in 1996

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O† | | | | | R-O-Rg | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha⁻¹ | | | | | | | | | |
| 19 Sept. | 310a B§ | 830b A | 520c B | 820c A | 0a C | 240a AB | 380c A | 110d A | 90c BC | 0b C |
| 17 Oct | 0b D | 1830a A | 870b C | 1210b B | 0a D | 0b | 1660a A | 440c B | 560b B | 0b C |
| 14 Nov | 0b D | 890b C | 1550b A | 1230b B | 0a D | 0b | 690b B | 910b A | 420b C | 0b D |
| 11 Dec | 0b B | 0c B | 1510a A | 1480a A | 0a B | 0b | 0d | 1140a A | 750a B | 160a C |
| SE | Planting date by period = 32 Mixture by period = 39 | | | | | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover
‡ P1 (before 21 Dec.), P2 (22 Dec. to 5 Feb.), P3 (6 Feb. to 20 Mar.), P4 (21 Mar. to 8 May), and P5 (after 8 May)
§ Values within a column followed by the same lower case letter are not different (P > 0.05) by LSD. Planting date by period and mixture by period interaction in 1996 (P < 0.0001)

Table A.2 Planting date by growth period interaction for rye-oat DM yield for cool-season forage mixtures planted at four planting dates in 1996

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Crim† | | | | | R-O-Rg-Crim | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 19 Sept | 210a A§ | 360c A | 190d A | 160c A | 0a | 200a A | 220c A | 110d A | 80b A | 0a |
| 17 Oct | 0b | 1490a A | 540c B | 340cb B | 0a | 0b | 1610a A | 370c B | 320a B | 0a |
| 14 Nov | 0b | 770b B | 1250b A | 530b C | 0a | 0b | 700b A | 730b A | 360a B | 0a |
| 11 Dec | 0b | 0d | 1500a A | 940a B | 20a | 0b | 0d | 1090a A | 550a B | 70a |
| SE | Planting date by period = 32 Mixture by period = 39 | | | | | | | | | |

† R = rye O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec.), P2 (22 Dec. to 5 Feb.), P3 (6 Feb. to 20 Mar.), P4 (21 Mar. to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by period and mixture by period interactions in 1996 ($P < 0.0001$)

Table A.3 Planting date by growth period interaction for rye-oat DM yield for cool-season forage mixtures planted at four planting dates in 1996

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Red† | | | | | R-O-Rg-Red | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 19 Sept | 250a AB§ | 370c A | 210c B | 100c B | 0a | 270a A | 240 b A | 130d B | 90b B | 0a C |
| 17 Oct | 0b D | 1670a A | 670b B | 430b C | 0a | 0b C | 1540a A | 420c B | 400a B | 0a C |
| 14 Nov | 0b D | 840b B | 1230a A | 460b C | 0a | 0b C | 640b A | 820b A | 430a B | 0a C |
| 11 Dec. | 0b C | 0 d C | 1510a A | 1480a B | 0a | 0b C | 0c | 1140a A | 750a B | 160a C |
| SE | Planting date by period = 32 Mixture by period = 39 | | | | | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec.), P2 (22 Dec to 5 Feb ), P3 (6 Feb to 20 Mar ), P4 (21 Mar to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD Planting date by period and mixture by period interactions in 1996 ($P < 0.0001$)

Table A.4 Planting date by growth period interaction for rye-oat DM yield for cool-season forage mixtures planted at four planting dates in 1997

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R O† | | | | | R-O-Rg | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha⁻¹ | | | | | | | | | |
| 2 Oct | - | - | 1090a A§ | 1070a A | 0 | - | - | 650a A | 220a B | 0 |
| 30 Oct | - | - | 1110a A | 1360a A | 0 | - | - | 620a A | 150a B | 0 |
| 25 Nov | - | - | 1230a A | 1040a A | 0 | - | - | 850a A | 20a B | 0 |
| 23 Dec. | - | - | 0b B | 1130a A | 0 | - | - | 0b A | 200a A | 0 |
| SB | Planting date by period = 54 Mixture by period = 66 | | | | | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec ), P2 (22 Dec to 5 Feb ), P3 (6 Feb to 20 Mar ), P4 (21 Mar to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD Planting date by period and mixture by period interaction in 1997 ($P < 0.0001$)

Table A.5 Planting date by growth period interaction for rye-oat DM yield for cool-season forage mixtures planted at four planting dates in 1997

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Crim† | | | | | R-O-Rg-Crim | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM $ha^{-1}$ | | | | | | | | | |
| 2 Oct. | - | - | 630a A§ | 670c A | 0 | - | - | 330a A | 410b A | 0 |
| 30 Oct | - | - | 550a B | 1220a A | 0 | - | - | 570a A | 810a A | 0 |
| 25 Nov | - | - | 810a A | 1030abc A | 0 | - | - | 440a A | 40c A | 0 |
| 23 Dec | - | - | 0b B | 1060ab A | 0 | - | - | 0 b B | 520ab A | 0 |
| SE | Planting date by period = 54 Mixture by period = 66 | | | | | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec.), P2 (22 Dec. to 5 Feb.), P3 (6 Feb. to 20 Mar.), P4 (21 Mar. to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by period and mixture by period interaction in 1997 ($P < 0.0001$)

Table A.6 Planting date by growth period interaction for rye-oat DM yield for cool-season forage mixtures planted at four planting dates in 1997.

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Red† | | | | | R-O-Rg-Red | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 2 Oct | - | - | 600a A§ | 570b A | 0 | - | - | 370a A | 360a A | 0 |
| 30 Oct | - | - | 680a A | 620b A | 0 | - | - | 390a A | 140ab A | 0 |
| 25 Nov | - | - | 640a A | 750 b A | 0 | - | - | 440a A | 0b B | 0 |
| 23 Dec. | - | - | 0b B | 1480a A | 0 | - | - | 0b B | 70ab A | 0 |
| SE | Planting date by period = 54 Mixture by period = 60 | | | | | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec.), P2 (22 Dec. to 5 Feb.), P3 (6 Feb. to 20 Mar.), P4 (21 Mar. to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by period and mixture by period interaction in 1997 ($P < 0.0001$)

Table A 7. Planting date by growth period interaction for ryegrass DM yield for cool-season forage mixtures planted at four planting dates in 1996

| Planting date | R-O-Rg† | | | | |
|---|---|---|---|---|---|
| | P1<br>(before 21 Dec ) | P3<br>(22 Dec to 5 Feb ) | P3<br>(6 Feb to 20 Mar ) | P4<br>(21 Mar to 8 May) | P5<br>(after 8 May) |
| | | | kg DM ha$^{-1}$ | | |
| 19 Sept | 110a B‡ | 170ab B | 150a B | 990b A | 0b B |
| 17 Oct | 0b C | 410a B | 350a B | 980b A | 180b BC |
| 14 Nov | 0b C | 230ab B | 260a B | 2160a A | 0b C |
| 11 Dec | 0b C | 0b C | 130a C | 660a B | 1190a A |
| | | | R-O-Rg-Crim | | |
| 19 Sept. | 70a A | 20b A | 30a A | 220a A | 120b A |
| 17 Oct | 0b B | 290a A | 140a A | 200a A | 140b A |
| 14 Nov | 0b C | 260a A | 80a BC | 370a A | 160b AB |
| 11 Dec | 0b B | 0b B | 210a A | 190a A | 400a A |
| | | | R-O Rg-Red | | |
| 19 Sept. | 90a A | 30b A | 30a A | 170a A | 30a A |
| 17 Oct | 0a B | 400a A | 110a B | 200a B | 0a B |
| 14 Nov | 0a B | 130b B | 110a B | 420a A | 30a B |
| 11 Dec. | 0a A | 0b A | 170a A | 220a A | 160a A |
| SE | Planting date by period = 48 | | Mixture by period = 42 | | |

† R = rye, O = oat, Rg = ryegrass. Crim = crimson clover, Red = red clover

‡ Values within a column followed by the same lower case letter are not different (P > 0 05) by LSD. Planting data by period and mixture by period interaction in 1996 (P < 0 0001).

Table A.8 Planting date by growth period interaction for ryegrass DM yield for cool-season forage mixtures planted at four planting dates in 1997

| Planting date | P1 (before 21 Dec) | P3 (22 Dec to 5 Feb) | P3 (6 Feb to 20 Mar) | P4(21 Mar to 8 May) | P5 (after 8 May) |
|---|---|---|---|---|---|
| | R-O-Rg† | | | | |
| | kg DM ha | | | | |
| 2 Oct | - | - | 160ab B‡ | 1100b A | 930bc A |
| 30 Oct | - | - | 160ab B | 1260b A | 1260b A |
| 25 Nov | - | - | 500a B | 2130a A | 630c B |
| 23 Dec | - | - | 0b C | 870b B | 1620a A |
| | R-O-Rg-Crim | | | | |
| 2 Oct | - | - | 100ab B | 640b A | 600a A |
| 30 Oct | - | - | 70ab B | 500b A | 0b A |
| 25 Nov | - | - | 480a B | 1740a A | 200ab B |
| 23 Dec | - | - | [illegible] | [illegible] | [illegible] |
| | R-O-Rg-Red | | | | |
| 2 Oct | - | - | 80 b B | 850b A | 440ab AB |
| 30 Oct. | - | - | 200b B | 990b A | 410ab AB |
| 25 Nov | - | - | 650a B | 1670a A | 120 b C |
| 23 Dec. | - | - | 0b B | 1020ab A | 900a A |
| SE | Planting date by period = 98 | | Mixture by period = 85 | | |

† R = rye O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover.

‡ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD Planting date by period ($P < 0.001$) and mixture by period interaction in 1997($P < 0.0008$)

Table A.9 Planting date by growth period interaction for clover DM yield for cool-season forage mixtures planted at four planting dates in 1996

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Crim† | | | | | R-O-Rg-Crim | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 19 Sept | - | - | - | 990a A§ | 670b B | - | - | - | 790a A | 380b B |
| 17 Oct | - | - | - | 760ab A | 450b B | - | - | - | 390b A | 290b A |
| 14 Nov | - | - | - | 570b B | 1450a A | - | - | - | 430b A | 650a A |
| 11 Dec | - | - | - | 0 c B | 1230a A | - | - | - | 0 c B | 380b A |
| SE | Planting date by period = 33 | | | | Mixture by period = 33 | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec.), P2 (22 Dec. to 5 Feb.), P3 (6 Feb. to 20 Mar.), P4 (21 Mar. to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by period and mixture by period interactions in 1996 ($P < 0.0001$)

Table A.10 Planting date by growth period interaction for clover DM yield for cool-season forage mixtures planted at four planting dates in 1997

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Crim† | | | | | R-O-Rg-Crim | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 2 Oct | - | - | 10a B§ | 580a A | 0b B | - | - | 20a B | 320a A | 0a B |
| 30 Oct | - | - | 10a B | 420ab A | 0b B | - | - | 20a A | 200a A | 0a A |
| 25 Nov | - | - | 20a B | 390ab B | 0b B | - | - | 60a A | 260a A | 30a A |
| 23 Dec | - | - | 0a C | 190b B | 850a A | - | - | 0a A | 60a A | 180a A |
| SE | Planting date by period = 44 | | | Mixture by period = 44 | | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec ), P2 (22 Dec to 5 Feb ), P3 (6 Feb to 20 Mar ), P4 (21 Mar to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD Planting date by period ($P = 0.0016$) and mixture by period interaction in 1997 ($P < 0.0001$).

Table A.11 Planting date by growth period interaction for clover DM yield for cool-season forage mixtures planted at four planting dates in 1996

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Red† | | | | | R O-Rg-Red | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 19 Sept | - | - | - | 300a B§ | 900a A | - | - | - | 160a B | 400a A |
| 17 Oct. | - | - | - | 40b B | 610ab A | - | - | - | 10b B | 590a A |
| 14 Nov | - | - | - | 60b B | 840a A | - | - | - | 10b B | 460a A |
| 11 Dec | - | - | - | 0b B | 320b A | - | - | - | 0b B | 180b A |
| SE | Planting date by period = 33 | | | | Mixture by period = 33 | | | | | |

† R = rye, O = oat, Rg = ryegrass, Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec ), P2 (22 Dec to 5 Feb.), P3 (6 Feb to 20 Mar ), P4 (21 Mar to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD Planting date by period and mixture by period interactions in 1996 ($P < 0.0001$)

Table A 12. Planting date by growth period interaction for clover DM yield for cool-season forage mixtures planted at four planting dates in 1997

| Planting date | Mixture | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R-O-Red† | | | | | R-O-Rg-Red | | | | |
| | P 1‡ | P 2 | P 3 | P 4 | P 5 | P 1 | P 2 | P 3 | P 4 | P 5 |
| | kg DM ha$^{-1}$ | | | | | | | | | |
| 2 Oct | - | - | 80a B§ | 260a B | 480a A | - | - | 80a B | 240a AB | 400a A |
| 30 Oct. | - | - | 10a B | 160a B | 490a A | - | - | 20a A | 40a A | 210ab A |
| 25 Nov | - | - | 90a B | 300a AB | 530a A | - | - | 100a A | 140a A | 160ab A |
| 23 Dec | - | - | 0 a B | 100a AB | 290a A | - | - | 0 a A | 40a A | 60 b A |
| SE | Planting date by period = 44 | | | Mixture by period = 44 | | | | | | |

† R = rye, O = oat, Rg = ryegrass. Crim = crimson clover, Red = red clover

‡ P1 (before 21 Dec ), P2 (22 Dec to 5 Feb ), P3 (6 Feb to 20 Mar ), P4 (21 Mar to 8 May), and P5 (after 8 May)

§ Values within a column followed by the same lower case letter are not different ($P > 0.05$) by LSD. Planting date by period ($P = 0.0016$) and mixture by period interaction in 1997 ($P < 0.0001$)

Table A.13 SAS statements for the estimation of fecal output. From Pond et al. (1987)

```
DATA,
DATA GRAZE1,
INFILE GRAZE,
INPUT ANIMAL TIME CR,
Y = CR,
PROC SORT, BY ANIMAL,
PROC NLIN INTER = 50 CONVERGENCE = 00001 METHOD = MARQUARDT, BY
ANIMAL,
PARMS K0 = 100 L1 = 05 TAU = 10,
BOUNDS K0>0, L1>0, TAU>0,
T = TIME - TAU,
If T<0 THEN GO TO ALPHA,
E1 = EXP (-L1 *T),
ONE = T*(L1**2)*E1,
MODEL Y = ((K0*L1*T)*(EXP(-L1*T)))/ 59635,
    DER. K0 = ONE,
    DER. L1 = T*L1*K0*E1*(2-L1*T);
    DER. TAU = K0*(L1**2)*E1*(L1*T-1 0),
GO TO BETA,
ALPHA,
    MODEL Y = 0,
        DER. K0 = 0,
        DER. L1 = 0,
BETA,
OUTPUT OUT = POINTS1 PREDICTED = YHAT RESIDUAL = RESID,
DATA OK, MERGE POINTS1 GRAZE1,
PROC SORT, BY ANIMAL,
PROC PLOT, BY ANIMAL,
    PLOT YHAT * TIME = '*' Y*TIME = '+' /OVERLAY,
     LABEL TIME = TIME AFTER DOSE, HOURS,
```

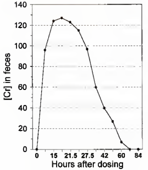

Figure A.1 Example of excretion curve of chromium (cow # 2824)

Table A.14 SAS program to adjust forage intake until fecal output observed and fecal output predicted differs by less than 0 01 kg/d (Moore and Kunkle personal communication)

Program terms

FRGDIG = forage digestibility
IVOMD = in vitro organic matter digestibility
FRGINTAK = forage intake
TOTINTAK = total intake (initially predicted from parameters derived from fecal excretion curves)
SUPINTAK = supplement intake (assumed constant)
TOTDIG = sum of digestible forage and digestible supplement intakes divided by total intake
FRGDIG = forage digestibility (determined from laboratory analysis)
SUPDIG = supplement digestibility (assumed constant)
FOP = fecal output predicted
FOO = fecal output observed
DIFF = difference of observed and predicted fecal output

```
>OMD is calculated in each iteration - call that the "expected" OMD
>Convert "expected" to "adjusted" with the following formula.
>adjusted OMD = 59 71 - 8948*(expected OMD) + 01399*(expected OMD)**2

Adapted by new equation Dr J.E Moore (2-19-99)
DATA RENINT1,
INFILE 'rennt1 TST',
INPUT SEA $ TRT REP CDW $ DMI FOO IVDMD SUPINTAK SUPDIG,
FRGDIG = IVOMD/100,
DO FRGINTAK =1 TO 40 BY 05 UNTIL (DIFF < 01);
TOTINTAK = FRGINTAK + SUPINTAK,
TOTDIG = (FRGINTAK*FRGDIG + SUPINTAK*SUPDIG)/TOTINTAK,
FOP = TOTINTAK*(1-TOTDIG),
DIFF = FOO-FOP,
END,
PROC PRINT,
RUN,
```

Table A.15 Cost of inputs for establishment and maintenance of two pasture systems

| Description | Amount ha$^{-1}$ | Date | Cost $ | Cost $ ha$^{-1}$ |
|---|---|---|---|---|
| **FERTILIZER** | | | | |
| Winter Pasture | | | | |
| - N (ammonium nitrate) | 40 kg | 12 Nov | 221 t$^{-1}$ | 29 09 |
| - 20-0-20 | 200 kg | 19 Dec | 188 t$^{-1}$ | 41 46 |
| - N (ammonium nitrate) | 40 kg | 12 Feb | 221 t$^{-1}$ | 29 09 |
| - N (ammonium nitrate) | 40 kg | 5 Mar | 221 t$^{-1}$ | 29 09 |
| - N (ammonium nitrate, berm.) | 40 kg | 14 Apr. | 221 t$^{-1}$ | 29 09 |
| Summer Pasture | | | | |
| - 10-10-20 | 400 kg | 10 June | 198 t$^{-1}$ | 87 32 |
| - N (ammonium sulphate) | 38 kg | 9 July | 176 t$^{-1}$ | 35.21 |
| - N (ammonium nitrate) | 40 kg | 13 Aug | 221 t$^{-1}$ | 29 09 |
| - N (ammonium nitrate, berm.) | 40 kg | 10 Sep | 221 t$^{-1}$ | 29 09 |
| **SEED** | | | | |
| Winter Pasture | | | | |
| System 1 (R-rg-clovers/pearl millet) | | | | |
| - Grazemaster rye | 68 kg | 23-24 Oct. | 0.55 kg$^{-1}$ | 37 48 |
| - Surrey ryegrass | 11 4 kg | | 1.10 kg$^{-1}$ | 12 57 |
| - Frame crimson | 10 kg | | 3.92 kg$^{-1}$ | 39.24 |
| - Cherokee red | 6 kg | | 4.32 kg$^{-1}$ | 25.93 |
| System 2 (R-rg/bermudagrass) | | | | |
| - Grazemaster rye | 91 kg | 23-24 Oct. | 0 55 kg$^{-1}$ | 50 15 |
| - Surrey ryegrass | 17 kg | | 1 10 kg$^{-1}$ | 18.74 |
| Summer Pasture | | | | |
| System 1 (R Rg-clovers/pearl millet) | | | | |
| - Tifleaf II pearl millet | 25 kg | 27 Apr | 1 12 kg$^{-1}$ | 28 11 |
| **PESTICIDE** | | | | |
| Herbicide | | | | |
| - Roundup | 5 L | 15 April | 12 53 L$^{-1}$ | 62 68 |
| Insecticide | | | | |
| -'Sevin' Carbaryl (1qt/A) | 2 34 L | 31 Aug | 6 64 L$^{-1}$ | 15.55 |

**PERENNIAL**

- Plow $ 25 00 ha$^{-1}$ - Harrow Disk $ 20 00 ha$^{-1}$
- Plow + 3 Disk $ 85 00 ha$^{-1}$ - Fertilizer application $ 7.50 ha$^{-1}$
- Planting bermudagrass = $ 250 00 to 625 00 ha$^{-1}$ 'Sprigging price $312.50 ha$^{-1}$ (Hay Stack Farms)
- Depreciation time base on 10 years

Table A.16 Total annual costs associated with pasture establishment and management.

| | Rye-ryegrass-clovers/ pearl millet | Rye-ryegrass/ bermudagrass |
|---|---|---|
| WINTER PASTURE | \$ ha$^{-1}$ | |
| Fertilizer | 128.73 | 157.82 |
| Seed | 115.22 | 68.89 |
| Establishment | 25.00 | 25.00 |
| Fertilizer Application | 30.00 | 37.50 |
| TOTAL | 298.95 | 289.21 |
| SUMMER PASTURE | | |
| Soil Preparation | 20.00 | - |
| Establishment | 25.00 | - |
| Establishment Depreciation | - | 39.76 |
| Fertilizer | 154.51 | 183.60 |
| Seed | 28.11 | - |
| Herbicide | 62.68 | - |
| Insecticide | - | 15.55 |
| Fertilizer Distribution | 22.50 | 30.00 |
| Herbicide Spraying | 20.00 | - |
| Insecticide Spraying | - | 20.00 |
| TOTAL | 332.80 | 288.91 |

Table A.17 Feedstuff costs for supplement formulation

| Ingredient | $ Ton (as-fed) | DM % |
|---|---|---|
| Alfalfa | 177.51 | 88.8 |
| Corn Silage | 38.59 | 26.7 |
| Brewers Grain | 38.18 | 21.0 |
| Hominy | 140.02 | 88.7 |
| Soybean meal | 230.76 | 89.0 |
| Soybean hulls | 86.00 | 91.0 |
| Whole cottonseeds | 156.08 | 88.4 |
| Cottonseed hulls | 74.42 | 90.0 |
| Citrus pulp | 93.71 | 89.6 |
| Distillers grain | 188.90 | 89.1 |
| Fish meal | 385.89 | 92.0 |
| Sodium bicarbonate | 427.69 | 100.0 |
| Herd mineral mix | 614.11 | 94.0 |
| Trace mineralized salt | 903.88 | 100.0 |
| Magnesium oxide | 411.38 | 100.0 |
| Limestone | 332.96 | 98.0 |

Table A.18. Cost of total mixed ration (TMR) for barn cows.

| Feedstuff | as-fed lb | as-fed kg | Ration as-fed | % | as-fed $\$\ t^{-1}$ | as-fed $\$\ kg^{-1}$ | as-fed $\$\ 100\ kg^{-1}$ |
|---|---|---|---|---|---|---|---|
| Corn silage | 40.0 | 18.16 | 0.400 | 40.0 | 38.59 | 0.039 | 1.544 |
| Alfalfa hay | 5.0 | 2.27 | 0.050 | 5.0 | 177.51 | 0.177 | 0.888 |
| Cottonseed hulls | 3.0 | 1.36 | 0.030 | 3.0 | 74.42 | 0.074 | 0.223 |
| Citrus pulp | 5.6 | 2.54 | 0.056 | 5.6 | 93.71 | 0.094 | 0.525 |
| Hominy | 10.5 | 4.77 | 0.105 | 10.5 | 140.02 | 0.140 | 1.471 |
| Distillers grains | 3.0 | 1.36 | 0.030 | 3.0 | 188.90 | 0.189 | 0.567 |
| Brewers grains | 20.0 | 9.08 | 0.200 | 20.0 | 38.18 | 0.038 | 0.764 |
| Soybean meal | 4.5 | 2.04 | 0.045 | 4.5 | 230.76 | 0.231 | 1.039 |
| Whole cottonseeds | 6.0 | 2.72 | 0.060 | 6.0 | 156.08 | 0.156 | 0.937 |
| Mineral mix | 2.0 | 0.91 | 0.020 | 2.0 | 614.11 | 0.614 | 1.228 |
| Limestone | 0.38 | 0.17 | 0.004 | 0.4 | 332.96 | 0.333 | 0.126 |
| Total | 99.98 | 45.39 | 1.00 | 100 | | | 9.311 |

1 kg TMR as-fed = $ 0.093

Table A.19 Cost of concentrate supplement for grazing cows (5 Jan. 1998).

| Feedstuff | as-fed<br>% | as-fed<br>$\$\,t^{-1}$ | as-fed<br>$\$\,kg^{-1}$ | as-fed<br>$\$\,100\,kg^{-1}$ | as-fed<br>$\$\,kg^{-1}$ |
|---|---|---|---|---|---|
| Hominy | 29.88 | 140.02 | 0.140 | 4.18 | |
| Whole cottonseeds | 19.40 | 156.08 | 0.156 | 3.03 | |
| Soybean hulls | 22.40 | 86.00 | 0.086 | 1.93 | |
| Citrus pulp | 14.94 | 93.71 | 0.094 | 1.40 | |
| Distillers grains | 5.98 | 188.90 | 0.189 | 1.13 | |
| Fish meal | 2.45 | 385.89 | 0.386 | 0.95 | |
| Herd mineral mix | 3.00 | 614.11 | 0.614 | 1.84 | |
| TMS | 0.23 | 903.88 | 0.904 | 0.20 | |
| Bicarbonate | 1.49 | 427.69 | 0.428 | 0.64 | |
| Magnesium oxide | 0.23 | 411.38 | 0.411 | 0.10 | |
| Total | 100.00 | | | 15.40 | 0.154 |

Table A.20 Cost of concentrate supplement for grazing cows (15 June 1998)

| Feedstuff | as-fed<br>% | as-fed<br>$\$\,t^{-1}$ | as-fed<br>$\$\,kg^{-1}$ | as-fed<br>$\$\,100\,kg^{-1}$ | as-fed<br>$\$\,kg^{-1}$ |
|---|---|---|---|---|---|
| Hominy | 26.9 | 140.02 | 0.140 | 3.77 | |
| Whole cottonseeds | 19.42 | 156.08 | 0.156 | 3.03 | |
| Soybean hulls | 22.4 | 86.00 | 0.086 | 1.93 | |
| Citrus pulp | 14.94 | 93.71 | 0.094 | 1.40 | |
| Distillers grains | 5.97 | 188.9 | 0.189 | 1.13 | |
| Soybean meal | 2.99 | 230.76 | 0.231 | 0.69 | |
| Fish meal | 2.46 | 385.89 | 0.386 | 0.95 | |
| Herd mineral mix | 2.99 | 614.11 | 0.614 | 1.84 | |
| TMS | 0.22 | 903.88 | 0.904 | 0.20 | |
| Bicarbonate | 1.49 | 427.69 | 0.428 | 0.64 | |
| Magnesium oxide | 0.22 | 411.38 | 0.411 | 0.10 | |
| Total | 100 | | | 15.66 | 1.566 |

Average 0.155 $kg^{-1}$ as-fed

Table A.21 Cost of one-shot supplement for grazing cows.

| Feedstuff | as-fed % | as-fed $\$ \, t^{-1}$ | as-fed $\$ \, kg^{-1}$ | as-fed $\$ \, 100 \, kg^{-1}$ | as-fed $\$ \, kg^{-1}$ |
|---|---|---|---|---|---|
| Hominy | 13.85 | 140.02 | 0.140 | 1.939 | |
| Whole cottonseeds | 14.97 | 156.08 | 0.156 | 2.336 | |
| Cottonseeds hulls | 18.49 | 74.42 | 0.074 | 1.376 | |
| Citrus pulp | 19.6 | 93.71 | 0.094 | 1.837 | |
| Distillers grains | 8.72 | 188.9 | 0.189 | 1.647 | |
| Soybean meal | 10.88 | 230.76 | 0.231 | 2.511 | |
| Soybean hulls | 10.88 | 86.00 | 0.086 | 0.936 | |
| Herd mineral mix | 1.24 | 614.11 | 0.614 | 0.761 | |
| TMS | 0.25 | 903.88 | 0.904 | 0.226 | |
| Bicarbonate | 0.99 | 427.69 | 0.428 | 0.424 | |
| Magnesium oxide | 0.12 | 411.38 | 0.411 | 0.049 | |
| | 99.99 | | | 14.043 | 0.1404 |

Table A.22 Total feed cost per system.

| System | Intake as-fed | Cost as-fed | Partial cost | | Total cost |
|---|---|---|---|---|---|
| | -kg $d^{-1}$- | -\$ $kg^{-1}$- | -\$ $cow^{-1}$ $d^{-1}$- | -\$ $cow^{-1}$ $d^{-1}$- | -\$ $cow^{-1}$ $d^{-1}$- |
| TMR | 45.13 | 0.093 | 4.202 | 4.202 | |
| System 1† | 12.87 | 0.151 | 1.943 | | |
| System 2‡ | 11.95 | 0.153 | 1.828 | | |
| - Pasture - Syst 1 | | | | 0.346 | |
| - Pasture - Syst 2 | | | | 0.302 | |
| - Corn silage-Syst 1§ | | 0.039 | 0.009 | 0.009 | |
| - Corn silage-Syst 2 | | 0.039 | 0.018 | 0.018 | |
| TMR | | | | | 4.202 |
| System 1 | | | | | 2.298 |
| System 2 | | | | | 2.148 |

† 12.87kg (\$ 0.155*73.5% time) + 12.7kg (\$ 0.14*26.5% time)

‡ 11.95kg (\$ 0.155*85% time) + 11.95kg (\$ 0.14*15% time)

§ silage 29d * 9kg as-fed (1 rep. in both systems) + 22d * 11kg as-fed (1 rep. System 2)

Table A.23 Cost of herbage DM consumed from pastures

| | Pasture winter | Pasture summer | |
|---|---|---|---|
| Pasture Costs | --\$ $ha^{-1}$-- | --\$ $ha^{-1}$-- | --\$ 1.5 $ha^{-1}$-- |
| System 1 | 298.95† | 332.80 | 465.35 |
| System 2 | 289.21 | 288.91 | 433.66 |

| | SR $cow\ ha^{-1}$ | d on-pasture | \$ $cow^{-1}$ | \$ $cow^{-1}$ $d^{-1}$ |
|---|---|---|---|---|
| System 1 | 4.87 | 276 | 95.55 | 0.346 |
| System 2 | 5.21 | | | |

† System 1 = rye-ryegrass-clovers/pearl millet System 2 = rye-ryegrass/bermudagrass

‡ Total (1 ha winter + 0.5 ha summer pastures)

Table A.24 Extent of utilization and amount of concentrate supplements fed per cow

| Intake (suppl) | d | kg cow$^{-1}$ d$^{-1}$ | Total kg cow$^{-1}$ |
|---|---|---|---|
| System 1 | 276 | 12.87 | 3552 |
| System 2 | 276 | 11.95 | 3298 |

| Intake one-shot (d) | winter | summer | one-shot | kg cow$^{-1}$ d$^{-1}$ |
|---|---|---|---|---|
| System 1 | 26.4 | 28.19 | winter | 18.2 |
| System 2 | - | 27.1 | summer | 16.3 |

Intake one-shot

|  | --d-- | -kg d$^{-1}$- | total --kg-- | d on pasture % total |
|---|---|---|---|---|
| winter |  |  |  |  |
| Syst 1 | 28.1 | 18.2 | 510 | 14.4 |
| Syst 2 | 27.1 | 18.2 | 492 | 14.9 |
| summer |  |  |  |  |
| Syst 1 | 26.4 | 16.3 | 432 | 12.2 |

| Type of supplement | System 1 | System 2 |
|---|---|---|
|  | — % of season — |  |
| normal | 73.5 | 85.0 |
| one-shot | 26.5 | 15.0 |

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Renato Serena Fontaneli was born in Passo Fundo, Rio Grande do Sul state, on 5 Feb. 1957. He is the older son of Reginaldo and Olga Fontaneli. He graduated from Faculdade de Agronomia of the Universidade de Passo Fundo in January 1982 and received his Engenheiro-Agrônomo degree. In March 1982, he joined the staff of the Universidade de Passo Fundo as an Assistant professor and researcher in pasture science. In March 1984, he was granted a scholarship by the CAPES/Ministério de Educação to study toward the degree of Master of Science at Universidade Federal do Rio Grande do Sul. In August 1989, he joined the staff of the Empresa Brasileira de Pesquisa Agropecuaria (Embrapa) at the National Wheat Research Center experimental station as a pasture researcher. In January 1996, through an Embrepa scholarship, he was accepted into a Doctor of Philosophy degree program in Agronomy at the University of Florida (UF). He has specialized in forage production systems and management under the direction of Dr. Lynn E. Sollenberger.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy

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